Terrestrial Magnetism

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Atmospheric Electricity

(Now entitled Journal of Geophysical Research)

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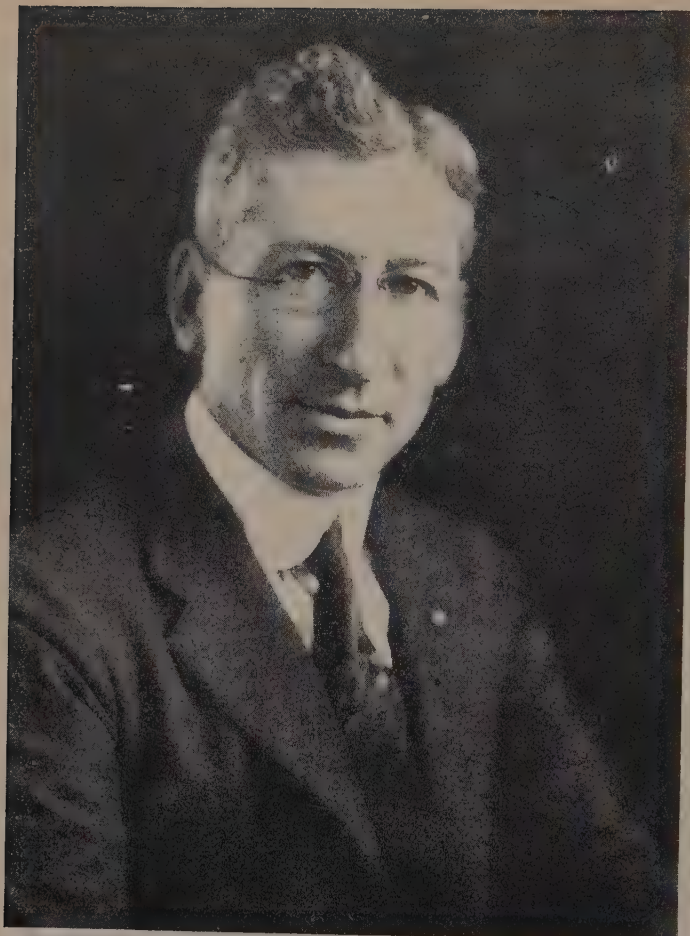

Sincerely yours,
S. J. Mauchly

Terrestrial Magnetism
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Atmospheric Electricity

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ON THE DIAMAGNETIC FIELD OF THE OUTER ATMOSPHERE

BY S. CHAPMAN

Abstract—The magnetic field of the diamagnetic layer in the outer atmosphere, to which R. Gunn has recently drawn attention, is examined, and shown to be remarkably similar to that of the daily magnetic variations.

INTRODUCTION

§1. In the 1928 July issue of the *Physical Review* R. Gunn[1] has shown that in the outer layer of the Earth's atmosphere, where the free-paths are long, the spiral motions of the ions round the lines of force of the Earth's magnetic field render the ionized air equivalent to a magnetized medium of intensity

$$\boldsymbol{i} = -(k\,\nu T/H^2)\boldsymbol{H} \tag{1}$$

where k is Boltzmann's constant 1.37×10^{-16}, ν is the number per cc of free charges (of either sign), T is the absolute temperature, $\boldsymbol{H}$ is the magnetic force (of intensity H). He attributes the solar daily magnetic variation (here, for brevity, to be referred to as S) to the magnetic field of this layer, which changes owing to the daily increase of ν during the hours of sunlight, and its decrease after nightfall. By an approximate calculation he shows that the layer might produce a daily variation of north force similar, in its distribution with respect to latitude, to that actually observed. The interest of Dr. Gunn's theory seems to me such as to warrant a more complete and accurate calculation of its consequences than is practicable with the methods that he adopts. The calculations here described show that the field of the diamagnetic layer is remarkably similar to the field of the daily magnetic variations.

[1] R. GUNN, *Phys. Rev.*, v. 32, July, 1928 (133-141); by the courtesy of Dr. E. O. Hulburt and Dr. Ross Gunn, I was privileged to see this paper in advance of publication.

The Magnetic Potential Ω of the Layer

§2. Let Ω denote the potential of the magnetic field of the layer in the space below the layer, Ω being such that the magnetic force in the direction of an element of arc ds is $-d\Omega/ds$. In calculating Ω, it will be assumed (a) that the layer is a spherical shell concentric with the Earth, and of radius qa, where a denotes the Earth's radius (6.4×10^8 cm), and $q>1$; (b) that the field H is that of a sphere uniformly magnetized along the geographical axis, so that, at north-polar distance θ, H and its components, H_r along the outward radius, and H_θ in the direction of increasing θ, are given by

$$(2) \qquad H^2=H_0^2\,(1+3\cos^2\theta),\ H_r=-2H_0\cos\theta,\ H_\theta=-H_0\sin\theta = -H_n$$

where H_0 is the magnetic force at the equator (approximately 0.3 C.G.S.), and H_n denotes the north component of H.

§3. Gunn made a calculation of Ω along the noon meridian by graphical quadratures, using the expression

$$(3) \qquad \Omega=-\int i\times\nabla(1/r)\,dV$$

where r denotes the distance from the point to which Ω refers, to the volume element dV of the layer. He took the value of μ along the noon meridian, at the equinox, as

$$(4) \qquad \nu=\nu_0\sin\theta$$

so that along this meridian

$$(5) \qquad i=[k\,\nu_0\,T/H_0]\ [\sin\theta/(1+3\cos^2\theta)^{1/2}]$$

He took the layer to be a shell 30 km thick, at height 150 km. Having found Ω by a graphical integration, taking account of the direction of the Earth's field at all points, a graphical differentiation gave the value of $\triangle H_n$, the corresponding modification of the north force. It is not clear how this graphical calculation of Ω was performed, or what was taken to be the value of ν over other than the noon meridian; an integration over the whole spherical shell seems almost impracticable. Moreover $\triangle H_n=d\Omega/a\,d\theta$ does not give directly the amplitude of the 24-hour component in the daily variation of H_n; it includes a contribution by the diamagnetic layer to the mean value of H_n for the day; it is not clear that this was allowed for. Fortunately, by another method, it is possible to make an approximate analytical calculation of Ω at all points over the Earth, from which all three components of the S-field can be deduced.

Analytical Calculation of Ω

§4. In the following calculation of Ω the shell is, for simplicity, assumed to be thin; this simplification will not materially affect the

results. In the computations the value of q has been taken as $1+\frac{1}{40}$, corresponding to a mean height of $\frac{1}{40}$ a, or 160 km, for the layer.

Since the shell is assumed thin we consider not ν, the ion-density, but $n = \int \nu \, dh$ integrated throughout the thickness of the layer; n is the total ion-content per sq. cm. column; likewise we consider not $\boldsymbol{i}$, but $\boldsymbol{I} \equiv \int \boldsymbol{i} \, dh$.

§5. The value of n at north-polar distance θ and local time ϕ (ϕ being the east longitude reckoned from the *noon* meridian) will be assumed to depend only on ω, the Sun's zenith distance. If δ is the Sun's north declination, then since the Sun is on the noon meridian

(6) $$\cos\omega = \cos\theta \sin\delta + \sin\theta \cos\delta \cos\phi$$

Let it be supposed that

(7) $$\begin{aligned} n &= n_0 + n_1 \cos\omega + n_2 \cos^2\omega. \\ &= n_0 + n_1 \cos\theta \sin\delta + n_2 [\cos^2\theta \sin^2\delta + (1/2)\sin^2\theta \cos^2\delta] \\ &\quad + (n_1 \sin\theta \cos\delta + 2\, n_2 \sin\theta \cos\theta \sin\delta \cos\delta) \cos\phi \\ &\quad + (1/2)\, n_2 \sin^2\theta \cos^2\delta \cos 2\phi \end{aligned}$$

If further powers of $\cos\omega$ had been included in n, it would, when expanded as a Fourier series in ϕ, include terms in $\cos 3\phi$, $\cos 4\phi$, . . ., and the coefficients of the terms above written would be modified. In order to account for the higher harmonic components known to exist in S (of frequency 3, 4, . . . , or period 8, 6, . . . hours) these higher powers of $\cos\omega$ would be necessary, but they are not considered here owing to the added complexity involved in subsequent calculations.

§6. Each term in the Fourier series for n will involve a corresponding term in Ω; it is convenient to denote the term in Ω corresponding to $\cos s\phi$ in n by Ω_s; the term $s=0$ only affects the mean value of H for the day, being constant round each circle of latitude.

§7. By (1), or the corresponding equation connecting I with n, we have for the r, θ components of I,

(8) $$I_r = -k\,n\,T\,H_r/H^2, \quad I_\theta = -k\,n\,T\,H_\theta/H^2,$$

or by (2)

(9) $$I_r = \frac{2\,k\,n\,T\,\cos\theta}{H_0\,(1+3\cos^2\theta)}, \quad I_\theta = \frac{k\,n\,T\sin\theta}{H_0\,(1+3\cos^2\theta)}$$

It will for simplicity be assumed that in these expressions T has a constant value (taken later as 300°); n is given by (7).

It can readily be shown that the distribution of tangential

magnetization I is equivalent to a distribution of magnetic matter of surface-density σ given by

$$\sigma = -\frac{1}{\sin\theta} \frac{d}{qad\theta} (I_\theta \sin\theta) \tag{10}$$

§8. The functions I_r and σ can be expressed in series of spherical harmonic functions S_m (θ, ϕ), as follows:

$$I_r = \Sigma\, \alpha_m S_m(\theta, \phi), \quad -q\, a\, \sigma = \Sigma\, \beta_m S_m(\theta, \phi) \tag{11}$$

It may readily be shown that Ω is then given by

$$\Omega = -4\pi\, \Sigma \frac{1}{2m+1} \left\{ (m+1)\, \alpha_m + \beta_m \right\} \left(\frac{r}{qa}\right)^m S_m(\theta, \phi) \tag{12}$$

Each harmonic function $S_m(\theta, \phi)$ of degree m is the sum of a number of terms each of which, in the present case, contains a factor $\cos s\phi$, where $s \leq m$; the typical term is $P_m{}^s$ $(\cos\theta)$ $\cos s\phi$, where

$$P_m{}^s = \frac{2m!\ \sin^s\theta}{2^m m!\,(m-s)!} \left\{ \cos^{m-s}\theta - \frac{(m-s)\,(m-s-1)}{2\,(2m-1)} \times \right.$$
$$\cos^{m-s-2}\theta + \frac{(m-s)\,(m-s-1)\,(m-s-2)\,(m-s-3)}{2.4\ (2m-1)\,(2m-3)} \times$$
$$\left. \cos^{m-s-4}\theta - \ldots\ldots\ \right\} = \sin^m\theta \frac{d^m}{d\cos\theta^m} P_n \tag{13}$$

§9. The functions and their expansions that are required in this paper are as follows, where the suffixes e, u refer to their even or uneven (odd) degree

$$f_e^0\,(\theta) = \frac{1}{1+3c^2} = \Sigma\, a_{2m}\, P_{2m},\quad f_u^0\,(\theta) = \frac{c}{1+3c^2} = \Sigma\, a_{2m+1}\, P_{2m+1} \tag{14, a, b}$$

$$g_e^0\,(\theta) = \frac{1}{(1+3c^2)^2} = b_{2m}\, P_{2m},\quad g_u^0\,(\theta) = \frac{c}{(1+3c^2)^2} = \Sigma\, b_{2m+1}\, P_{2m+1} \tag{15, a, b}$$

$$f_e^1\,(\theta) = \frac{sc}{1+3c^2} = \Sigma\, a^1_{2m}\, P^1_{2m},\quad f_u^1\,(\theta) = \frac{s}{1+3c^2} = \Sigma\, a^1_{2m+1}\, P^1_{2m+1} \tag{16, a, b}$$

$$g_e^1\,(\theta) = \frac{sc}{(1+3c^2)^?} = \Sigma\, b_{2m}{}^1 P_{2m}{}^1,\quad g_u{}^1(\theta) = \frac{s}{(1+3c^2)^?} = \Sigma\, b^1_{2m+1}\, P^1_{2m+1} \tag{17, a, b}$$

$$(18)\quad f_u^2\ (\theta)=\frac{s^2c}{1+3c^2}=\Sigma\ a^2{}_{2m+1}\ P^2{}_{2m+1}$$

$$(19)\quad g_u^2\ (\theta)=\frac{s^2c}{(1+3c^2)^2}=\Sigma\ b^2{}_{2m+1}\ P^2{}_{2m+1}$$

A function $f\ (\theta)\cos s\ \phi$ in I_r or σ can be expressed as the sum of a number of harmonic functions $a_m{}^s\ P_m{}^s\cos s\phi$, the coefficients $a_m{}^s$ being determined by

$$(20)\quad a_m{}^s=\frac{2m+1}{2}\ \frac{(m-s)!}{(m+s)!}\int_{-1}^{1}f\ (\theta)\ P_m{}^s\ d\cos\ \theta;$$

these integrals, for the above functions f and g, can be integrated in finite terms, though the process is tedious for the higher harmonics.

§10. As an alternative method, or as a check on the results, the following recurrence-formulæ may be used, which only require a_0 and b_0 to be found by direct integration.

$$(21)\quad a_1=1-a_0,\quad a_{2n+1}=-\frac{1}{3}\ \frac{4n+3}{2n+1}\ a_{2n}-\frac{4n+3}{4n-1}\ \frac{2n}{2n+1}\ a_{2n-1}$$

$$(22)\quad a_{2n+2}=\frac{4n+5}{2n+2}\ a_{2n+1}-\frac{4n+5}{4n+1}\ \frac{2n+1}{2n+2}\ a_{2n}$$

$$(23)\quad b_{2n+1}=\frac{4n+3}{2n+1}\left\{\frac{1}{3}\ (a_{2n}-b_{2n})-\frac{2n}{4n-1}\ b_{2n-1}\right\}$$

$$(24)\quad b_{2n+2}=\frac{4n+5}{2n+2}\left\{b_{2n+1}-\frac{2n+1}{4n+1}\ b_{2n}\right\}$$

$$(25)\quad a^1{}_{2n}=\frac{a_{2n-1}}{4n-1}-\frac{a_{2n+1}}{4n+3}$$

$$(26)\quad a^1{}_{2n+1}=\frac{a_{2n}}{4n+1}-\frac{a_{2n+2}}{4n+5}$$

$$(27)\quad b^1{}_{2n}=-\frac{1}{6}\ a_{2n}$$

$$(28)\quad b^1{}_{2n+1}=\frac{1}{2}\ (a_{2n+1}+a^1{}_{2n+1})$$

$$(29)\quad a^2{}_{2n+1}=\frac{a^1{}_{2n}}{4n+1}-\frac{a^1{}_{2n+2}}{4n+5}$$

$$(30)\quad b^2{}_{2n+1}=-\frac{1}{6}\ a^1{}_{2n+1}$$

These formulæ are found as follows: For (21) multiply (14b) by c, giving (1/3) $(1-f_e{}^0)$ on the left; the right is then transformed by using the formula

(31) $(2n+1)\ c\ P_n = (n+1)\ P_{n+1} + n\ P_{n-1}$

afterwards equating coefficients of P_{2n+1} on the two sides of the equation; the same method, applied to (14a), (15, a, b) gives (22, 23, 24). To get (25, 26) multiply (14 a, b) by s and use the formula

(32) $(2n+1)\ P_n = P'_{n+1} - P'_{n-1}$

(where $'$ denotes differentiation with respect to c) to transform the right-hand sides. To get (27, 28), differentiate (14b) with respect to c and multiply by s. To get (29, 30), divide (16 a, b) by s, so that $P_n{}^1$ on the right becomes P_n'; differentiate both sides with respect to c, and use (32) likewise differentiated.

§11. The following are the values of the a's and b's used in this paper: where $\alpha = (\pi/9)\sqrt{3}$

$$a_0 = \alpha \qquad b_0 = \frac{1}{8} + \frac{1}{2}\alpha$$

$$a_2 = 5\left(\frac{1}{2} - \alpha\right) \qquad b_2 = -\frac{5}{8}$$

$$a_4 = -\frac{45}{4} + 19\alpha \qquad b_4 = \frac{27}{4} - \frac{21}{2}\alpha$$

$$a_6 = 13\left(\frac{63}{20} - \frac{47}{9}\alpha\right) \qquad b_6 = 13\left(-\frac{27}{8} + \frac{50}{9}\alpha\right)$$

$$a_8 = 17\left(-\frac{9.257}{280} + \frac{41}{3}\alpha\right) \qquad b_8 = 17\left(\frac{9.23}{16} - \frac{11.35}{18}\alpha\right)$$

$$a_1 = 1 - \alpha \qquad b_1 = -\frac{1}{8} + \frac{1}{2}\alpha$$

$$a_3 = -\frac{7}{2} + \frac{49}{9}\alpha \qquad b_3 = \frac{21}{8} - \frac{14}{3}\alpha$$

$$a_5 = 11\left(\frac{23}{20} - \frac{17}{9}\alpha\right) \qquad b_5 = \frac{11}{2}(-3 + 5\alpha)$$

$$a_7 = -\frac{9.137}{28} + \frac{5.131}{9}\alpha \qquad b_7 = \frac{9.71}{8} - \frac{17.70}{9}\alpha$$

$$a_2^1 = \frac{5}{6} - \frac{10}{9}\alpha \qquad b_2^1 = -\frac{5}{12} + \frac{5}{6}\alpha$$

$$a_4^1 = -\frac{33}{20} + \frac{8}{3}\alpha \qquad b_4^1 = \frac{15}{8} - \frac{19}{6}\alpha$$

$$a_6^1 = 13\left(\frac{11}{35} - \frac{14}{27}\alpha\right) \qquad b_6^1 = 13\left(-\frac{21}{40} + \frac{47}{54}\alpha\right)$$

$$a_8^1 = 17\left(-\frac{3.59}{280} + \frac{254}{243}\alpha\right) \qquad b_8^1 = 17\left(\frac{3.257}{560} - \frac{41}{18}\alpha\right)$$

$$a_1^1 = -\frac{1}{2} + 2a \qquad b_1^1 = \frac{1}{4} + \frac{1}{2}\,a$$

$$a_3^1 = 7\,(\frac{1}{4} - \frac{4}{9}\,a) \qquad b_3^1 = 7\,(-\frac{1}{8} + \frac{1}{6}\,a)$$

$$a_5^1 = 22\,(-\frac{1}{5} + \frac{1}{3}\,a) \qquad b_5^1 = 11\,(\frac{3}{8} - \frac{11}{18}\,a)$$

$$a_7^1 = \frac{9.71}{56} - \frac{170}{9}\,a \qquad b_7^1 = -\frac{9.29}{16} + \frac{5.97}{18}\,a$$

$$a_3^2 = 7\,(\frac{1}{20} - \frac{2}{27}\,a) \qquad b_3^2 = 7\,(-\frac{1}{24} + \frac{2}{27}\,a)$$

$$a_5^2 = 11\,(-\frac{19}{420} + \frac{2}{27}\,a) \qquad b_5^2 = 11\,(\frac{1}{15} - \frac{1}{9}\,a)$$

$$a_7^2 = \frac{53}{56} - \frac{380}{243}\,a \qquad b_7^2 = -\frac{3.71}{112} + \frac{85}{27}\,a$$

§12. On inserting the value of n from (7) into (8) and calculating σ by (10), the following expressions are obtained for I_r and $-qa\sigma$, in terms of the functions f, g of §9

$$(34) \quad I_r = (2\,knT/H_0)\Big[n_0 f_u^0 + \frac{1}{3} n_1 (1 - f_e^0) \sin\delta + n_2 \Big\{ \frac{1}{6} (4f_u^0 - c) + (\frac{1}{2} c - f_u^0) \sin^2\delta \Big\} + \Big\{ n_1 f_e^1 \cos\delta + \frac{1}{3} n_2 (s - f_u^1) \sin 2\delta \Big\} \cos\phi + \frac{1}{2} n_2 f_u^2 \cos^2\delta \cos 2\phi \Big]$$

$$(35) \quad -qa\sigma = (knT/H_0)\Big[8\,n_0 g_u^0 + \frac{1}{3} n_1 (4\,f_e^0 - 8\,g_e^0 + 1) \sin\delta + n_2 \Big\{ \frac{1}{3} (16\,g_u^0 - c) - (8\,g_u^0 - c) \sin^2\delta \Big\} + \Big\{ n_1 (8\,g_e^1 + f_e^1) \cos\delta + \frac{1}{3} n_2 (2s + 3f_u^1 - 8\,g_u^1) \sin 2\delta \Big\} \cos\phi + n_2 (4\,g_u^2 + f_u^2) \cos^2\delta \cos 2\phi \Big]$$

The corresponding expression for Ω can be deduced from (11, 12) by the aid of (14 to 19); it is convenient to divide it into

parts Ω_{me}, Ω_{mu}, where e, u refer to the even or odd degree of the harmonic function, and m (=0, 1, 2) to the frequency. Then it is found that, writing

(36) $x=r/qa,\ A_m=(4\,\pi\,k\,T/a\,H_0)\,n_m,\ (m=0,\ 1,\ 2),$

and ignoring the constant term in Ω_{0e}

(37) $$-\Omega_{0e}/a=-\frac{2}{3}\,A_1\sin\delta\sum_{m=1}^{\infty}\frac{x^{2m}\,P_{2m}}{4m+1}\left\{(2m-1)\,a_{2m}+4\,b_{2m}\right\}$$

(38) $$-\Omega_{0u}/a=4\sum_{m=0}^{\infty}\frac{x^{2m+1}\,P_{2m+1}}{4m+3}\left[\left\{(m+1)\,a_{2m+1}+2\,b_{2m+1}\right\}\left\{A_0+A_2\left(\frac{2}{3}-\sin^2\delta\right)\right\}\right]-A_2\left(\frac{1}{3}-\sin^2\delta\right)x\,P_1$$

(39) $$-\Omega_{1e}/a\cos\phi=A_1\cos\delta\sum_{m=1}^{\infty}\frac{x^{2m}\,P^1{}_{2m}}{4m+1}\left\{(4m+3)\,a^1{}_{2m}+8b^1{}_{2m}\right\}$$

(40) $$-\Omega_{1u}/a\cos\phi=\frac{1}{3}A_2\sin 2\delta\left[2\,x\,P^1{}_1-\sum_{m=0}^{\infty}x^{2m+1}\frac{P^1{}_{2m+1}}{4m+3}\left\{(4m+1)\,a^1{}_{2m+1}+8\,b^1{}_{2m+1}\right\}\right]$$

(41) $$-\Omega_{2u}/a\cos 2\phi=A_2\cos^2\delta\sum_{m=1}^{\infty}\frac{x^{2m+1}\,P^2{}_{2m+1}}{4m+3}\left\{(2m+3)\,a^2{}_{2m+1}+4\,b^2{}_{2m+1}\right\}$$

(42) $$-\Omega_{2e}/a\cos 2\phi=0$$

By inserting the values of the coefficients a, b from §11 into these formulæ the following are obtained as the numerical forms of the above results, to the degree of approximation here adopted

(43) $$-\Omega_{0e}/a=A_1\sin\delta\left\{0.40307\,x^2P_2{}^0-0.17178\,x^4P^0{}_4+0.06749\,x^6P_6{}^0-0.02545\,x^8P_8{}^0+\ldots\right\}$$

(44) $$-\Omega_{0u}/a=\left\{A_0+A_2\left(\frac{2}{3}-\sin^2\delta\right)\right\}\left\{xP_1{}^0-0.46258\,x^3P_3{}^0+0.18773\,x^5P_5{}^0-0.07204\,x^7P_7{}^0+\ldots\right\}-A_2\left(\frac{1}{3}-\sin^2\delta\right)x\,P_1$$

$$(45) \quad -\Omega_{1e}/a \cos\phi = A_1 \cos\delta \left\{ 0.36565\, x^2 P_2^1 - 0.08128\, x^4 P_4^1 + 0.02165\, x^6 P_6^1 - 0.00618\, x^8 P_8^1 + \ldots\ldots \right\}$$

$$(46) \quad -\Omega_{1u}/a \cos\phi = A_2 \sin 2\delta \left\{ 0.09693\, x P_1^1 + 0.09581\, x^3 P_3^1 - 0.02393\, x^5 P_5^1 + 0.00664\, x^7 P_7^1 - \ \ldots\ldots \right\}$$

$$(47) \quad -\Omega_{2u}/a \cos 2\phi = A_2 \cos^2\delta \left\{ 0.03855\, x^3 P_3^2 - 0.00521\, x^5 P_5^2 + 0.00100\, x^7 P_7^2 - \ldots\ldots \right\}$$

From these expressions the contributions of the diamagnetic layer to $\triangle N$, $\triangle W$, and $\triangle Z$, the surface variations ($r=a$) of the north, west, and (downward) vertical components of magnetic force, can be calculated, using:

$$(48) \quad \triangle N = \partial\Omega/a\partial\theta,\ \triangle W = \partial\Omega/a \sin\theta\partial\phi,\ \triangle Z = \partial\Omega/\partial r$$

Such calculations have been made, taking $q=1+\frac{1}{40}$, and $\delta=0$, $\delta=20°$, for each 10° of latitude, in terms of A_0, A_1, A_2. Before considering these results, it may be noticed that Ω_{0e}, Ω_{1u} change sign with δ, and represent the main part of the seasonal variation of the field; Ω_{0u}, Ω_{1e}, Ω_{2u}, for $\delta=0$, represent the diamagnetic field at the equinoxes, and it is in accordance with observation that in the two latter the principal terms are P_2^1, P_3^2 respectively.

§13. The simplest form of n, and that corresponding most closely to the one used in Gunn's calculation of Ω (cf. §3, (6)) is

$$(49) \quad n = n_0 + n_1 \cos\omega$$

where, in order that n may nowhere be negative,

$$(50) \quad n_1 \leq n_0$$

The maximum magnetic variation corresponding to the form (49) for n is obtained by taking

$$(51) \quad n_1 = n_0$$

corresponding to $n=0$ at the point antipodal to the Sun, and $n=2n_0$, or twice the mean value n_0, at the point directly beneath the Sun.

At the equinoxes ($\delta=0$) this gives

(52) $n=n_0\,(1+\sin\theta\cos\phi)$

and

(53) $\Omega={}_{0u}\Omega+\Omega_{1e}$

then the diamagnetic layer affects the mean value of H, and also contributes a daily variation of period 24 hours (and no other).

The value of $\triangle N$ and $\triangle W$ have been calculated in this case in terms of $A\equiv A_{max}$ ($=2A_0$ in this case), the only remaining unknown. The diamagnetic layer does not affect the mean value of the west component of force; its effect on the daily mean value of the north component is

(54) $\triangle N_0=\partial\Omega_{0u}/a\,\partial\,\theta\equiv N_0$

The periodic terms in $\triangle N$, $\triangle W$, derived from Ω_{1e}, will be denoted by

(55) $\triangle_1 N=N_1\cos\phi$, $\triangle_1 W=W_1\sin\phi$

The values of N_0/A, N_1/A, W_1/A are shown in sections (*a*), (*b*), (*c*) of Fig. 1. In (*a*), (*b*) the various harmonic terms contributing to the fourth approximation (shown by a full line) are indicated by short broken lines; in (*c*) the last approximation shown is the third, indicated by longer broken lines. The convergence of the numerical formulæ is satisfactory, and the fourth approximation must be very nearly accurate.

Curves (*b*) (*c*) for $N_1/A_{\max}$ and $W_1/A_{\max}$ are in good general agreement with the observed latitude-distribution of the amplitudes of the 24-hour term in the daily variation of north and west magnetic force; the reversal of sign of N_1 at about 30° latitude, the high value of N_1 at the equator as compared with its value in temperate latitudes, and the ratio of N_1 to W_1, the latter being of opposite sign in the two hemispheres—all these features agree approximately with observation. The expression (45) for Ω_{1e}/a, including terms P_4^1, P_6^1, P_8^1, ... as well as P_2^1, agrees better with observation than does the term P_2^1 alone, though in my spherical harmonic analysis[2] of S I used only this single term, as the data were insufficient to give good determinations of the coefficients of the higher harmonics.

Curve Fig. 1 (*b*) is on the whole similar to Gunn's Fig. 2, giving the result of his calculation (§3), though his figure shows a small depression at the equator; he gives also (his Fig. 3) a curve showing the observed values of N_1, which likewise has such a depression, but I do not think the evidence for this is strong. The present calculation of N_1 seems likely to be the more accurate for reasons

[2]S. CHAPMAN, London, *Phil. Trans. R. Soc., A.*, 218, 1919, p. 1.

stated in §3; the curves for N_1 and W_1 are qualitatively favorable to his theory.

§14. From (55) it is evident that the maximum north force should occur at noon ($\phi = 0°$) when N_1 is positive, as it is between $\pm 30°$ latitude: likewise the maximum west declination should occur at 6 p. m. ($\phi = 90°$) in the northern hemisphere, where W_1 is positive. Actually $\triangle_1 N$ attains its maximum 1.5 to 2 hours before midday (*cf.* my analysis of S, *loc. cit.*, p. 27, giving the phase e_{mn} of the external part of the S-field). This phase-difference between the theory and observation, though not large, is difficult to account for, because it implies that the diamagnetic layer attains its maximum degree of ionization well before noon, whereas it would be expected to occur at or slightly after noon. While the diamagnetic theory comes near to accounting for S, at least qualitatively, in a far simpler and more direct way than the dynamo theory is able to do, yet the simplicity of the former seems to render it the less capable of adjustment to meet small discrepancies. Hence the fact that the magnetic variations are earlier in phase than the diamagmagnetic theory predicts is a serious qualitative difficulty for the theory.

§15. Fig. 1 (a) shows that the contribution of the diamagnetic layer to the mean value of the north force H_n is positive and approximately equal to N_1 at the equator; it diminishes rapidly with increasing latitude, and beyond $\pm 40°$ latitude is negligible.

The observed amplitudes N_1 and W_1 of the daily magnetic variation S (here considering only the 24-hour component) are observed to be nearly twice as great at a high sunspot-maximum as at a sunspot-minimum. Whatever the theory of S, this increase must be explained by an increase in the ion-content of the upper atmosphere, and on the diamagnetic theory the increase must be proportional to that of S, that is, n must be doubled; on the dynamo theory the ion-content (in this case referring to the region below the level of long free-paths) may be increased to a smaller extent. On the diamagnetic theory, assuming, as is natural, that the relative distribution of n over the Earth remains constant, a general increase in n will involve equal ratios of increase in N_0, N_1 and W_1. Thus if N_1 is increased from about 15γ to 30γ at the equator, as is observed, N_0 should increase by a similar amount, and therefore the diamagnetic theory predicts a fluctuation of the mean value of H_n by about 15γ at the equator, from sunspot-minimum to maximum, and back again to minimum; this should be superposed on the general secular variation. Such a fluctuation is well within the limits of measurement with modern instruments, but unfortunately there are no long series of past tropical observations of H_n of sufficient accuracy to test the prediction. I have examined the Batavian annual mean values of H_n, for 1884 to 1923, but the irregular variations are too large to reveal a regular sunspot-cycle variation of 15γ. The only suggestion I have been able to find

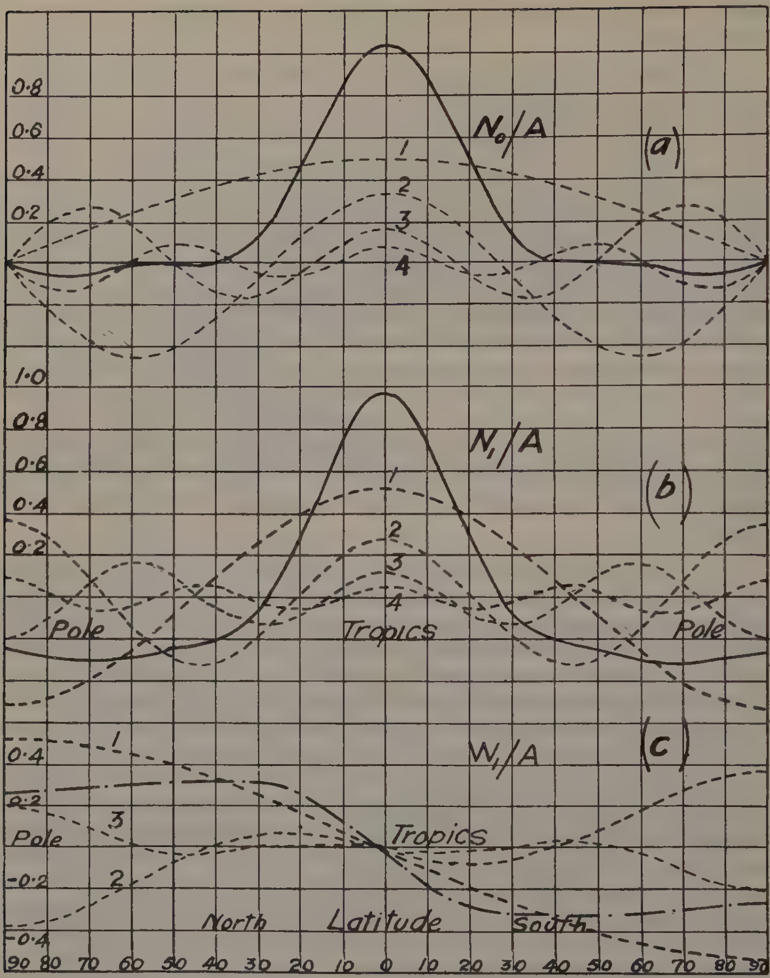

Fig. 1

in the literature of a sunspot-influence on the secular variation, is in a paper by Leyst[3], and it refers to the declination, which according to the diamagnetic theory should not be affected; Chree ("Studies in Terrestrial Magnetism," p. 17) considered that Leyst's conclusions were not warranted by the evidence. Fig 1 (*a*) indicates that an appreciable effect of the kind is to be expected, in H_n only, almost solely at tropical stations.

§16. So far the consequences of the diamagnetic theory have

[3]Leyst, Moskva, *Bull. Soc. Nat.*, 1909, p. 160.

been worked out on the basis of a specially simple form (49) of n, and for the equinoxes, when the Sun is in the equatorial plane. The presence, at the equinoxes and solstices alike, of terms in S of frequency higher than the first, that is, of periods 12, 8, 6, ... hours as well as 24 hours, depending on $\cos 2\phi$, $\cos 3\phi$, $\cos 4\phi$, ..., shows that on the diamagnetic theory a more complex expression for n than (49) is needed; (49) represents n as increasing steadily but slowly, from a minimum value at the point antipodal to the Sun, to a maximum directly under the Sun; the slowness of the increase may be indicated by comparing $n_{\max}$, the maximum (noon) value, with n_0, the value round the twilight circle ($\cos\omega=0$), and $\overline{n}$, $\overline{n_s}$, $\overline{n_d}$, the mean values of n over the whole earth and over the sunlit and dark hemispheres respectively. When, as in (52), $n_1=n_0$, we have

$$(56)\quad n_{\max}:\overline{n_s}:\overline{n}:n_0:\overline{n_d}=2:3/2:1:1:1/2$$

Actually, it seems likely that n will be low during the night, rise rapidly after sunrise and decrease rapidly again towards and after sunset. Such a variation requires further terms in $\cos\omega$ in the expression for n; indeed n must be periodic in ω with as many components as appear in S[4]. In the present paper we shall not consider terms of frequency higher than 2, but such terms could easily be treated by the methods here adopted. The magnetic potential for the expression (7) for n is given in §12, (43 to 47); the 12-hour component (Ω_{2u}) depends on n_2 (or A_2) alone, while the main 24-hour component (Ω_{1e}) depends on n_1 (or A_1) alone: hence n_2 must have a definite ratio to n_1 in order to give the observed ratio between the first and second components of S. These two comments are approximately in the same phase (*l. c.*, [2], p. 27, $e_m{}^n$) and since the expressions in brackets $\{$ . . . . $\}$ in (45, 46) have the same sign at the equator, it follows that n_2 and n_1 must have the same sign: the additional term $n_2\cos^2\omega$ in n must, in fact, correspond to a more rapid increase of n to its midday maximum than can be represented by (49); this accords with expectation.

§17. The expression for n of the form (7) which will be considered, is that already used in my former paper[2] upon S, namely

$$(57)\quad n=n_0\left(1+3\cos\omega+\frac{9}{4}\cos^2\omega\right)=n_0\left(1+\frac{3}{2}\cos\omega\right)^2$$

To this correspond the ratios

$$(58)\quad n_{\max}:\overline{n_s}:\overline{n}:n_0:\overline{n_d}=6.25:3.25:1.75:1:0.25$$

showing that (57) represents a very considerable difference of ionization between the dark and sunlit hemispheres; it may be noted that according to (57) n falls to zero for $\cos\omega=-2/3$, and thence

[4]This constitues another difference between the diamagnetic and dynamo theories; in the latter even the simple form (49) for n introduces terms in S of all frequencies, and (7) introduces third and fourth harmonics of the observed magnitude, if $n_1=-3\,n_0$, $n_2=\frac{9}{4}\,n_0$, as in (58).

rises to a small midnight maximum value of $1/4n_0$, which will not correspond to the actual circumstances—but this is unavoidable if (7) is to represent a really rapid rise of n over the sunlit hemisphere, so long as no terms of higher degree in cos ω are included. The unreal secondary maximum of n is, however, so small as to be unlikely to affect the calculations appreciably. This form of n was found[2] to give a good representation of the harmonics of frequencies 1 to 4 in the lunar diurnal magnetic variation at the equinoxes on the dynamo theory.

§18. The values of the harmonic series in brackets $\{ \ldots . \}$ in (43 to 57) have been calculated for each 10° of latitude, and also the corresponding series in $\partial\Omega/a\partial\theta$. The results have been expressed in terms of n_{max} or A, where (cf. 36)

$$(59) \quad A = A_{max} = (4\pi kT/aH_0)\, n_{max}$$

using the ratios (58); further, the values −20°, 0°, 20° have been assigned to δ, corresponding to periods near the solstices, and at the equinoxes. The results corresponding to the expression (57) for n are shown graphically in Fig. 2, sections (a to e). Section (a) refers to the change, due to the diamagnetic layer, in the mean value of H_n, at each latitude and season; in this and all the other sections of the figure the full line represents the equinoctial distribution, and the broken lines the solstitial ones. Sections (b), (c) refer to the 24-hour component of $\triangle N$ and $\triangle W$ respectively, and sections (d, e) likewise to the 12-hour component. Figs. 1 and 2 are on the same scale, so that they can be directly compared, assuming the same value of n_{max} in each case.

No detailed comparison of these figures with the observed data will be made, but they may be said to show, on examination, a considerable degree of similarity with the observed distribution of S in the north and west components. Moreover, by choosing n_1 and n_2 in (7) in somewhat different ratios to n_0, some of the features in which Fig. 2 does not accord closely with observation might be improved: among these are (a) the excessive value of N_1 at the equator as compared with N_1 above latitude 30°, and as compared with W_1, and (b) the seasonal variations, which as calculated are in general too small. To remedy these defects it would be necessary to modify (7) so as to represent a more extreme variation between day and night than (57) affords; this can be done by adding terms in $\cos^3\omega$, $\cos^4\omega$, ... , which would also introduce third and fourth harmonics in S, as actually observed. The calculations could easily be extended, by the present methods, to take account of such terms, should the diamagnetic theory in the future gain support from observations of the degree of ionization of the outer atmosphere.

§19. Up to this stage the diamagnetic theory has been considered without reference to the absolute magnitude of the diamagnetic

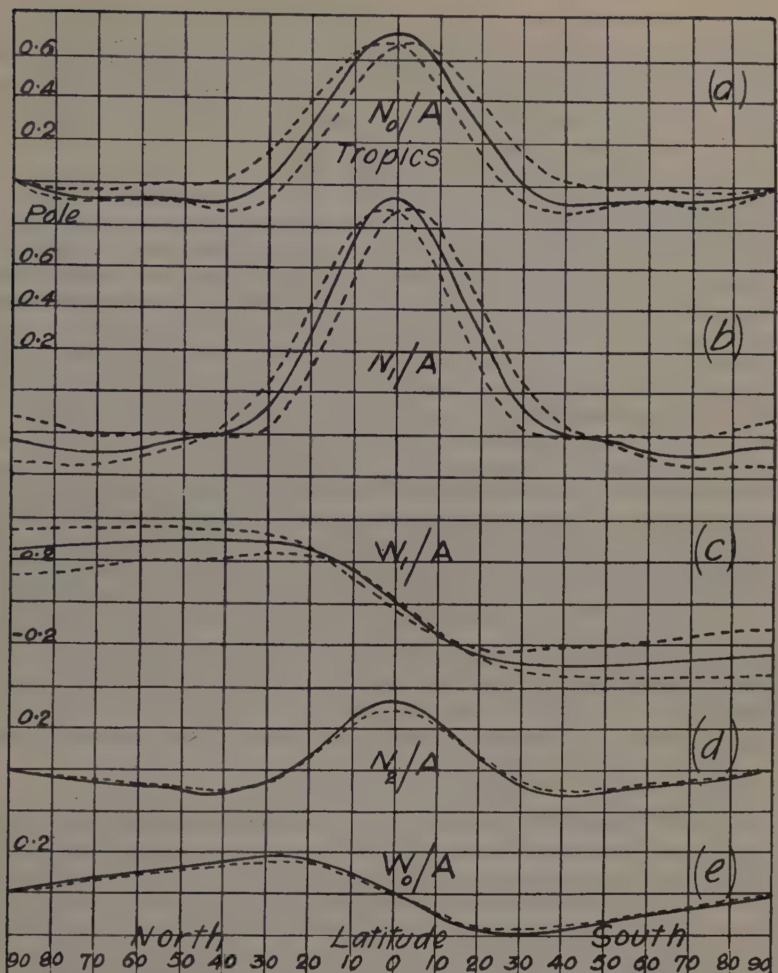

Fig. 2

field, since the unknown factor A or $A_{\max}$ (*cf.* 59), depending upon $n_{\max}$, has been retained in the formulæ throughout the discussion. If Gunn's hypothesis is provisionally adopted, the necessary value of $n_{\max}$ can be evaluated from the observations. The observed value of N for the external part of the S-field at the equator is approximately 13γ (*l. c.*,[2] p. 27, from $E_2{}^1$), or 1.3×10^{-4} c.g.s. Equating this to the calculated equinoctial value of N_1/A, from Fig. 2 (*b*), viz., 0.94, we obtain $A=1.4\times10^{-4}$, whence, taking $T=300°$, $a=6.4\times10^8$, $H_0=0.3$, $k=1.37\times10^{-16}$, we find that

$$(60)\qquad n_{\max}=5.2\times10^{16}$$

R. Gunn's estimate was 15×10^{16}. These numbers are so large as to be difficult to explain; n_{max} is equal to the total number of electrons per cm^2 column above about 60 km (at which height their free-path is long enough to permit them to spiral freely about the Earth's lines of force, the "spiral-radius" for electrons being about 2 cm at the equator, and 1 cm at the magnetic poles), and of ions above about 140 km (the greater height being because of the greater spiral radius for ions, viz., about 400 and 200 cm at the equator and poles respectively). It is of interest to compare the above estimate of n_{max} with the value to be derived from the important discussion of the electrical properties of the upper atmosphere recently given by P. O. Pedersen[5]: this value is approximately 5×10^{13}, or less than (60) in the ratio 10^{-3}. But the present uncertainties as to the ionization of the upper atmosphere are such that even this discrepancy can hardly be considered fatal to the theory. E. V. Appleton's recent discovery that there is an ionized layer at 250 km height in the atmosphere was not taken account of in P. O. Pedersen's discussion, so that the value 5×10^{13} for n_{max} may be too low. The probability is, however, that though the diamagnetism of the outer atmosphere must undoubtedly contribute to S, and in a manner remarkably similar to the observed form and distribution of S, yet its contribution is only a minor part of the whole.

In conclusion I wish to record the valuable help I have received from Miss M. C. Cray in making the calculations involved in this paper, and from Mr. W. Reeve in the preparation of the two diagrams.

[5] P. O. PEDERSEN, The propagation of radio waves, Copenhagen, 1927: *cf.* Appendix, p. 10, fig. IX, 6.

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THE DIAMAGNETIC THEORY OF UNDISTURBED TERRESTRIAL-MAGNETIC VARIATIONS[1]

By Ross Gunn

In an earlier paper[2] the writer outlined a theory of the terrestrial-magnetic variations based on diamagnetism existing in the upper atmosphere. The diamagnetism of the region was shown to follow from simple considerations of the motion of ions or electrons which spiralled about the Earth's magnetic field as a result of their thermal agitation. It is the purpose of this paper to extend the original ideas and supply certain evidence supporting the theory that was not advanced in the original paper.

It has been shown[2] that the intensity of magnetization I of an ion gas due to the thermal agitation of the ions is given by

$$\mathrm{I} = -NmV^2/2H = -NkT/H \qquad (1)$$

where N is the number of ions of all kinds per cubic centimeter, m the mass of the ion, V the component of the velocity of the ion perpendicular to the impressed magnetic field H, k the Boltzmann constant, and T the absolute temperature. These relations have been deduced on the assumption that the free-path is long and it becomes necessary to establish a criterion for the existence of long free-paths. The free-path, λ, of an ion in a gas made up of N molecules or ions per cubic centimeter, and having a kinetic-theory diameter σ is given by

$$\lambda = 1/\sqrt{2}\,\pi\,\sigma^2 N \qquad (2)$$

In the high atmosphere of the Earth it seems well established that the diamagnetic effects are largely due to ions rather than electrons. It will therefore be assumed that the free-path of the ion is long and the diamagnetic effect large if the free-path is equal to or greater than the radius of the helix generated by the ion as it spirals about the impressed magnetic field. The radius, r, of the helix may be obtained by equating the centrifugal and magnetic forces acting on the ion, and if the velocity is then expressed in terms of the absolute temperature

$$r = \sqrt{2mkT}/eB \qquad (3)$$

Therefore, the critical molecular density, which may not be greatly exceeded is given by equating (3) and (2) which yields

$$N_{\mathrm{crit}} = eB/2\pi\sigma^2\sqrt{mkT} \qquad (4)$$

[1]Published by permission of the Navy Department.

[2]*Phys. Rev.*, v. 32, 1928 (133).

Putting in the appropriate values for a typical ion in the Kennelly-Heaviside layer, namely oxygen, and assuming B=0.4

$$N_{crit} = 2.0 \times 10^{12} \tag{5}$$

A close examination shows that N_{crit} is a conservative estimate and actually the effect persists strongly even when the densities are many times the limiting value which has just been selected. In the upper atmosphere of the Earth, the ionization is greatest in just those regions where the free-path is long and the greatest number of the ions is found where the requirements for the existence of diamagnetism as specified by equation (5) have been met.

In the earlier work[2] an estimate was made of the ionic density which would account for the observed effects based on the assumption that the maximum change in H at the equator was 40 gammas. This estimate showed that the number of ions per cubic centimeter at noon at the equator is 5×10^{10} or about two per cent of the total number of ions or molecules allowed by equation (5). Further consideration of the problem showed that this estimate was much too high and that certain systematic errors had crept into the original graphical integration. This has now been corrected and the

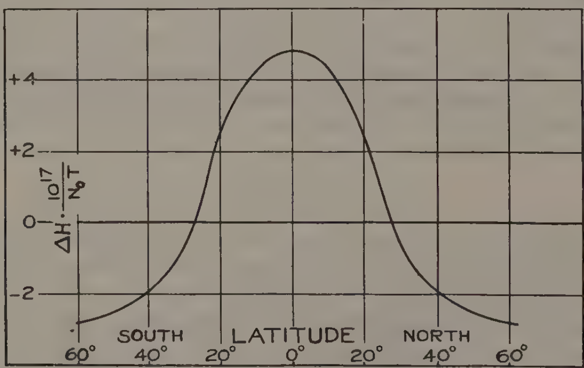

FIG. 1—Revised computed maximum variation in terms of N_0T

new plot of $\triangle H$ as a function of latitude is given in Figure 1. The form of the new curve which replaces Figure 2 of the original paper is more nearly in accord with the curve plotted from observed data. It has been brought to the writer's attention, moreover, that the numerical value of $\triangle H$ which was selected for the maximum variation at the equator (40 gammas) was actually about 25 gammas which would farther reduce the value of N_0 necessary to account for the observed variations.

Some recent interesting calculations by Maris and Hulburt[3]

[2]*Phys. Rev.*, v. 33, 1929 (412-431).

indicate that the temperature of the ionized layer in daytime is much larger than has been generally supposed. Their provisional calculations place the absolute temperature of this region at 1000° or higher. Equation (1) shows that the intensity of magnetization is dependent directly on the absolute temperature as well as on the ionization. Thus if the absolute temperature at high levels is in accordance with the conclusions of Maris and Hulburt, the contribution of each ion will be increased by a factor of three or more and the number of ions necessary to produce the observed effects will be reduced by the same factor.

This readjustment of the numerical magnitudes which are taken to be typical of the diurnal variation all tend to reduce the original estimate of the number of ions necessary to account for the observed effects without altering in any way the fundamental theory. Taking all the factors which have been discussed into account it seems probable that the required maximum number of ions per cubic centimeter at the equator is 5×10^9 or possibly even less. The problem of accounting for an ionic density of even 5×10^9 ions/cc can not be discussed in detail here and even so, conclusions regarding the ionization at high altitudes are not yet possible. It is evident, however, that the ionic density computed will depend in a very critical manner on the assumptions made regarding the pressures, absorption-coefficients, etc., of the gases in the high atmosphere. There are few available data on these questions, and any of the present estimates must be taken as highly tentative. Calculations made by Hulbert[4] which are believed to be based on the best available data and appear to be the only ones that take into account diffusion in the stratosphere, predict an ionic density which is in accord with the revised estimate given above.

One interesting and important feature of the diamagnetic theory is that it predicts the occurrence of the maximum variation before noon. It is well known that the height of the ionized layer undergoes changes in mean altitude due to the expansion of the lower-lying gaseous layers and that this change in altitude is comparable to the total height. Radio data yield information in regard to the altitude at which a certain ionic density exists, but unfortunately throw no light on the average height of the ionized layer.

The thermal inertia of the atmosphere is such that in general the maximum expansion and maximum average temperature occur some time after high noon. The height of the layer, therefore, becomes greater from sunrise till about 2 P. M., after which it falls. Thus each magnetic element is gradually moved upward and its effect on the Earth's surface is decreased till some time after noon. To formulate the consequences of this effect more precisely let us study what happens to the variation-field when the altitude of the mean layer varies with the time of day. For simplicity we may assume that the density of ionization N at a latitude ϕ and an hour-angle δ

[4] *Phys. Rev.*, v. 31, 1928 (1018).

measured eastward from the noon meridian may be represented at equinox by

$$N = N_0 + N_1 \cos\phi \cos\delta \qquad (6)$$

where N_0 is the residual ionization that persists throughout the night and which produces a steady field on the Earth probably small in comparison to the contribution of the second term. N_1 is the maximum number of ions per cubic centimeter produced at the equator by the incident sunlight. In this discussion we are interested in the variation-field so we shall consider the second or variable term only. The mean altitude of the diamagnetic layer will depend on the incident radiation and on the average thermal capacity of the atmosphere. Due to the thermal capacity of the atmosphere, the mean temperature and hence the mean height of the layer will not be a maximum when the incident energy is a maximum, but will lag behind by an angle η. In general the average temperature may be taken to be a maximum at about 2 P. M. corresponding to an angle $\eta = 30°$. It is evident therefore, that at any given latitude, (that is, ϕ = constant) the average height of the layer may be represented approximately by

$$h = h_0 + h_1 \cos(\delta - \eta) \qquad (7)$$

where h_0 is the average mean height of the layer and h_1 the amplitude of the variation of the mean height. The variation of the magnetic field at any given point on the surface of the Earth due to magnetic elements which are substantially overhead is secured by summing up terms whose coefficients are of the form

$$NT/Hh^3 \qquad (8)$$

or

$$N_0 T \cos\delta / H[h_0 + h_1 \cos(\delta - \eta)]^3 \qquad (9)$$

A differentiation of this expression with respect to the hour-angle δ shows that to a first approximation it has a maximum when

$$\sin\delta = -(3h_1/h) \sin\eta \qquad (10)$$

This relation applies only to the overhead elements which make the greatest contribution to the effect and must be modified but slightly to represent conditions exactly. Since η in equation (10) must always be greater than zero it follows that the maximum variation-field must occur before noon. If we take $\eta = 30°$, $h_1 = 0.2h$, then $\delta = -17°.5$, or the maximum variation of the horizontal component of the field in middle latitudes occurs slightly more than an hour before noon local time. It is of some interest to note that at the equator and high magnetic latitudes the contribution to the local horizontal field by regions overhead is small and therefore it would be expected that near the equator and poles the maximum change in the horizontal component would occur at or very near noon. The declination, on the other hand, would be expected

to pass through its zero-value well before noon at all latitudes. Such evidence as is available seems to indicate that this is precisely the case. Prediction in regard to the vertical components is not easily made since these are complicated relatively more by induced currents which may modify considerably the resultant field.

An approximate graphical integration has been carried out in order to determine how $\triangle H$ changes with the local time when account is taken of the contributions from all regions. The result of this integration carried out for a latitude of 45° is shown in Figure 2.

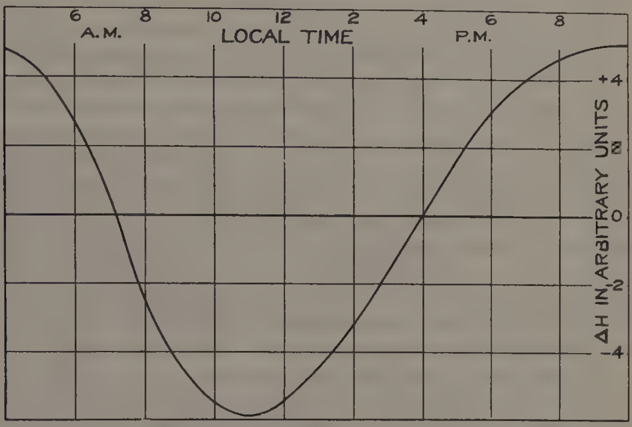

FIG. 2—Computed approximate form of the daily variation of the Earth's magnetic horizontal component taking into account the variable height of the diamagnetic layer at latitude 45°

It will be seen that the form of the resulting curve bears a certain resemblance to that actually observed and suggests that the assumption of a constant temperature needs modification.

The re-examination of the diamagnetic theory has shown that certain readjustments of the quantities involved were desirable, but fortunately each reasonable modification has been in a direction which favors the view rather than otherwise. The simplicity of the viewpoint and the freedom from numerous assumptions and adjustments are thought to be points favoring the reality of the theory. In conclusion it is perhaps well to emphasize that an important feature of the diamagnetic theory not shared by others is that the phenomena producing the effects are energetic and do not depend on vanishingly small electromotive forces to produce large circulating currents in circuits *which may not be closed.*

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REVIEWS AND ABSTRACTS

(See also pages 62 and 83)

BENNDORF, H., und V. F. HESS: *Luftelektrizität.* Müller-Pouillet, Lehrbuch der Physik, 11. Auflage, Bd. 5, Teil 1 (519-661). Braunschweig, Friedr. Vieweg und Sohn, 1928.

This is the most extensive treatise on the subject of atmospheric electricity to appear since the publication in 1924 of the "Traité d'électricité atmosphérique et tellurique" by E. Mathias and collaborators. The authors have shown a fine sense of values in the utilization of the space at their disposal. Following a brief historical sketch a very readable review presents the features and brings out the relations between them and thus leads to a recognition of the fundamental problems in this field. In the body of the text all the important methods of measuring the various elements and the essential principles underlying these are given. An abundance of tables and curves summarize the results of measurements. Among the topics of this treatise which deserve special mention are: (*a*) "The agents which ionize the atmosphere" in which the distribution of radioactive materials in the Earth and the atmosphere is given thorough quantitative consideration. Under this heading a discussion of the penetrating radiation and the ultra-gamma (or cosmic) radiation covers eight pages. Under (*b*) "The ion-destroying processes" are summarized the results of important recent work. When the results of (*a*) and (*b*) are applied to a consideration of (*c*) "The ionic equilibrium of the atmosphere," the number of ions observed both over land and sea are more satisfactorily accounted for than heretofore. (*d*) "The Earth's normal undisturbed field," the most extensive topic in this treatise, covers 41 pages. The collection of electrostatic principles having direct bearing on measurements of the Earth's field, the table of activity-constants for different types of collectors, and the discussion of practical aspects and sources of error are features which will be helpful to observers and to those who are concerned with the appraisal of measurements of the Earth's field. (A typographical error occurs in the charging coefficient of the Russelvedt mechanical collector; this should be 4600 instead of 46.00.) "The normal space charge of the atmosphere" which is a section under this topic, has received more attention than in other treatises.

In the eight pages allotted to the electric field of thunderstorms the recent developments are adequately discussed. Under the last topic which is entitled "The electric currents in the atmosphere" are found discussions of "The vertical conduction current," "The electric charge on precipitation," the theories of "The formation of the electric charge on precipitation," "The mechanism of thunderstorms," "Luminous discharges" such as lightning, St. Elmo's fire, etc., and in conclusion "A retrospect" in which several theories which have been proposed to account for the maintenance of the Earth's charge are reviewed. In this connection the authors also consider the vertical currents which are indicated by the magnetic line-integrals, as a possible companion problem to that of the maintenance of the Earth's charge and conclude: "There are here, therefore, two major problems which as yet defy solution but, with the present increasing interest in geophysics, it is to be hoped that before another generation the solution will be found and one can surmise that this solution may have far-reaching importance in pure physics."

O. H. GISH

PRELIMINARY RESULTS OF OCEAN MAGNETIC OBSERVATIONS ON THE *CARNEGIE* FROM BALBOA TO EASTER ISLAND TO CALLAO, OCTOBER, 1928, TO JANUARY, 1929[1]

BY J. P. AULT, *Commanding the Carnegie*

TABLE 1—*Preliminary Magnetic Results on Cruise VII of Carnegie, Pacific Ocean, October, 1928, to January, 1929.* (*Observers:* J. P. Ault, O. W. Torreson, F. M. Soule, W. E. Scott, L. A. Jones, and J. H. Paul)

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1928	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Oct. 25[c]	8 11 N	280 26	4.9 E	...	...	+0.1	−0.1	−0.1	...	...	...	...	...	...
27	5 56 N	280 10	...	32.4 N	.319	...	...	...	+2.0	−0.1	+0.7	+2	−2	+1
29	4 22 N	280 15	5.9 E	...	...	+0.3	0.0	+0.2	...	...	...	...	...	...
29	4 18 N	280 12	...	29.4 N	.321	...	...	...	+1.2	−0.1	+0.6	+2	0	+3
29	3 51 N	280 01	6.0 E	...	...	+0.2	−0.1	+0.2	...	...	...	...	...	...
30	2 55 N	279 32	5.8 E	...	...	−0.3	−0.6	−0.3	...	...	...	...	...	...
31	4 11 N	278 32	6.6 E	...	...	+0.4	+0.2	+0.6	...	...	...	...	...	...
31	4 16 N	278 27	5.7 E	...	...	−0.5	−0.7	−0.3	...	...	...	...	...	...
31	4 21 N	278 22	...	28.9 N	.321	...	...	...	+1.6	−0.1	+0.6	+1	−3	+1
31	5 04 N	277 47	6.5 E	...	...	+0.3	0.0	+0.4	...	...	...	...	...	...
Nov. 1	5 57 N	277 05	6.6 E	...	...	+0.4	+0.1	+0.5	...	...	...	...	...	...
2	4 47 N	277 34	...	...	.322	...	...	...	...	...	...	+2	−3	+1
2	4 43 N	277 38	...	29.4 N	...	...	...	...	+1.9	+0.2	+0.8	...	...	...
3	3 20 N	278 42	6.6 E	...	...	+0.3	0.0	+0.4	...	...	...	...	...	...
4	2 22 N	279 14	...	...	.321	...	...	...	...	...	...	+4	−1	+4
4	2 24 N	279 07	...	25.5 N	...	...	...	...	+1.6	+0.1	+0.6	...	...	...
5	1 48 N	279 16	6.8 E	...	...	+0.4	+0.1	+0.5	...	...	...	...	...	...
5	1 10 N	279 19	6.9 E	...	...	+0.4	0.0	+0.4	...	...	...	...	...	...
6	0 55 N	278 46	6.6 E	...	...	−0.1	−0.4	−0.2	...	...	...	...	...	...
6	0 24 N	278 45	7.0 E	...	...	+0.2	0.0	+0.1	...	...	...	...	...	...
7	0 16 S	278 19	7.5 E	...	...	+0.4	+0.2	+0.4	...	...	...	...	...	...
7	0 23 S	278 08	...	20.0 N	.320	...	...	...	+1.4	−0.9	+1.1	+6	−1	+5
8	1 33 S	277 45	7.3 E	...	...	−0.2	−0.4	−0.2	...	...	...	...	...	...
8	1 24 S	277 06	7.9 E	...	...	+0.3	+0.1	+0.3	...	...	...	...	...	...
9	1 20 S	275 21	...	17.2 N	.322	...	...	...	+1.0	+0.2	+0.8	+6	−1	+6
9	1 22 S	274 34	8.6 E	...	...	+0.4	+0.2	+0.3	...	...	...	...	...	...
10	1 34 S	273 11	8.9 E	...	...	+0.5	+0.1	+0.2	...	...	...	...	...	...
10	1 42 S	272 33	9.0 E	...	...	+0.4	+0.1	+0.1	...	...	...	...	...	...
11	1 51 S	271 24	9.2 E	...	...	+0.5	+0.2	+0.1	...	...	...	...	...	...
11	1 52 S	271 14	...	13.5 N	.326	...	...	...	−0.3	+0.1	−0.4	+7	−1	+5
11	1 47 S	270 25	9.4 E	...	...	+0.5	+0.2	+0.2	...	...	...	...	...	...
12	1 29 S	269 00	9.3 E	...	...	+0.3	−0.1	0.0	...	...	...	...	...	...
12	1 16 S	268 18	9.9 E	...	...	+0.9	+0.5	+0.5	...	...	...	...	...	...
14	1 51 S	265 34	...	11.1 N	.330	...	...	...	−0.6	+0.1	+0.3	+6	−2	+4

[a]Charts used for comparison: U. S. Hydrographic Office charts 1700, 1701, and 2406 for 1925; British Admiralty charts 777 for 1927, 3598 and 3603 for 1922; Reichs-Marine-Amt. charts Tit. XIV, 2, 2a, and 2b for 1920. All chart-values have been corrected to 1928.5 on account of secular-change rate indicated by the respective charts. The chart-differences are obtained by subtracting the chart-values from those determined on the *Carnegie*, east declination, north inclination, and horizontal intensity being reckoned as positive and west declination and south inclination as negative.

[b]Expressed in units of third decimal C. G. S.

[c]The *Carnegie* was at Balboa, Canal Zone, during October 11 to 25, 1928.

[1]For previous values obtained on Cruise VII, see *Terr. Mag.*, v. 33, pp. 121-128, and pp. 189-194.

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S
1928	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Nov. 14	1 59 S	265 24	9.9 E	...	...	+0.6	+0.2	+0.3	...	...	...	...	...	...
15	2 26 S	264 22	9.9 E	...	...	+0.5	+0.1	+0.2	...	...	...	...	...	...
15	2 41 S	263 41	10.2 E	...	...	+0.7	+0.3	+0.5	...	...	...	...	...	...
16	3 02 S	261 57	...	7.1 N	.330	...	...	...	−0.5	−0.3	+0.4	+6	−1	+4
17	3 14 S	260 23	10.2 E	...	...	+0.5	+0.3	+0.4	...	...	...	...	...	...
17	3 21 S	259 25	10.0 E	...	...	+0.2	0.0	+0.1	...	...	...	...	...	...
18	3 54 S	257 44	...	3.6 N	.333	...	...	...	−1.1	0.0	−0.4	+8	+2	+5
18	4 12 S	256 37	9.8 E	...	...	−0.1	−0.2	−0.2	...	...	...	...	...	...
19	5 06 S	254 27	9.8 E	...	...	−0.2	−0.1	−0.2	...	...	...	...	...	...
20	6 29 S	253 27	10.0 E	...	...	−0.1	0.0	0.0	...	...	...	...	...	...
20	6 42 S	253 19	...	3.1 S	.328	...	...	...	−1.2	+0.3	+0.4	+6	0	+3
20	7 28 S	252 46	9.7 E	...	...	−0.4	−0.6	−0.4	...	...	...	...	...	...
21	8 55 S	251 48	10.1 E	...	...	−0.2	−0.2	−0.1	...	...	...	...	...	...
21	9 52 S	251 11	10.5 E	...	...	+0.1	+0.1	+0.3	...	...	...	...	...	...
22	11 16 S	250 14	10.3 E	...	...	−0.3	−0.3	−0.1	...	...	...	...	...	...
22	12 10 S	249 35	...	14.4 S	.319	...	...	...	+0.5	−0.2	+0.3	+4	−1	+2
22	12 29 S	249 18	10.5 E	...	...	−0.3	−0.3	0.0	...	...	...	...	...	...
23	14 44 S	247 50	11.2 E	...	...	+0.1	+0.1	+0.3	...	...	...	...	...	...
24	16 24 S	247 05	...	22.4 S	.315	...	...	...	0.0	−0.1	+0.2	+4	0	+4
24	17 17 S	246 44	11.2 E	...	...	−0.4	−0.5	−0.2	...	...	...	...	...	...
25	18 51 S	246 00	11.3 E	...	...	−0.6	−0.7	−0.4	...	...	...	...	...	...
25	19 48 S	245 51	11.0 E	...	...	−1.1	−1.0	−1.0	...	...	...	...	...	...
26	21 32 S	245 37	...	30.8 S	.308	...	...	...	−0.1	−0.1	−0.2	+4	−1	+4
26	22 12 S	245 33	12.4 E	...	...	−0.4	−0.4	−0.2	...	...	...	...	...	...
27	23 06 S	245 17	12.6 E	...	...	−0.4	−0.3	−0.2	...	...	...	...	...	...
27	23 40 S	245 13	12.9 E	...	...	−0.2	−0.2	0.0	...	...	...	...	...	...
28	24 24 S	244 49	12.6 E	...	...	−0.8	−0.8	−0.4	...	...	...	...	...	...
28	24 56 S	244 32	...	35.7 S	.302	...	...	...	−0.2	+0.2	−0.1	+2	−4	+2
28	25 12 S	244 28	13.3 E	...	...	−0.3	−0.2	+0.1	...	...	...	...	...	...
29	26 23 S	244 38	13.4 E	...	...	−0.6	−0.5	−0.1	...	...	...	...	...	...
30	28 00 S	244 51	...	39.4 S	.298	...	...	...	+0.3	+0.1	+0.4	+3	−4	+3
30	28 31 S	244 58	14.5 E	...	...	−0.2	0.0	+0.3	...	...	...	...	...	...
Dec. 1	29 01 S	245 12	14.5 E	...	...	−0.4	−0.3	+0.1	...	...	...	...	...	...
1	29 35 S	245 22	14.7 E	...	...	−0.4	−0.2	+0.1	...	...	...	...	...	...
2	30 16 S	245 38	15.6 E	...	...	+0.3	+0.4	+0.7	...	...	...	...	...	...
2	30 23 S	245 40	...	42.4 S	.293	...	...	...	−0.3	−0.3	0.0	+2	−5	+2
2	30 59 S	246 01	15.8 E	...	...	+0.2	+0.4	+0.6	...	...	...	...	...	...
3	31 23 S	246 58	15.6 E	...	...	−0.2	−0.1	+0.1	...	...	...	...	...	...
3	31 33 S	247 50	16.5 E	...	...	+0.5	+0.8	+0.8	...	...	...	...	...	...
4	31 37 S	249 15	16.4 E	...	...	+0.3	+0.5	+0.6	...	...	...	...	...	...
4	31 13 S	250 12	...	42.4 S	.291	...	...	...	−0.3	−0.5	−0.2	+3	−3	+2
4	30 50 S	250 36	15.8 E	...	...	−0.1	−0.1	+0.1	...	...	...	...	...	...
5	29 20 S	251 12	15.8 E	...	...	+0.3	+0.4	+0.6	...	...	...	...	...	...
5	28 11 S	251 13	15.3 E	...	...	+0.2	+0.3	+0.6	...	...	...	...	...	...
6	27 17 S	250 40	14.8 E	...	...	+0.1	+0.2	+0.5	...	...	...	...	...	...
13[d]	27 56 S	250 52	15.1 E	...	...	+0.1	+0.3	+0.5	...	...	...	...	...	...
13	28 02 S	250 49	...	38.6 S	.294	...	...	...	−0.5	−0.5	−0.7	+3	−5	0
13	28 37 S	250 54	14.5 E	...	...	−0.7	−0.6	−0.3	...	...	...	...	...	...
14	29 08 S	251 03	15.6 E	...	...	+0.2	+0.3	+0.4	...	...	...	...	...	...
16	32 00 S	249 15	16.0 E	...	...	−0.2	−0.1	+0.1	...	...	...	...	...	...
16	31 58 S	249 45	16.5 E	...	...	+0.2	+0.3	+0.5	...	...	...	...	...	...
17	31 51 S	250 17	16.1 E	...	...	−0.2	−0.1	0.0	...	...	...	...	...	...

[d]The *Carnegie* was at Easter Island from December 6 to 12, 1928.

ate	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	I	H	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
928	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
c.17	31 50 S	250 26	......	43.3 S	.288	.....	.....	.....	−0.7	−0.8	−0.5	+1	−5	−1
17	31 39 S	250 53	15.9 E	......	......	−0.4	−0.3	−0.2	.....	.....	.....	.....	.....	.....
18	31 45 S	250 51	15.9 E	......	......	−0.4	−0.3	−0.3	.....	.....	.....	.....	.....	.....
19	32 19 S	252 30	17.6 E	......	......	+0.9	+0.9	+1.0	.....	.....	.....	.....	.....	.....
19	32 34 S	252 40	......	43.1 S	.287	.....	.....	.....	−0.2	−0.3	0.0	+3	−3	+1
20	33 49 S	253 13	17.5 E	......	......	+0.2	+0.2	+0.3	.....	.....	.....	.....	.....	.....
20	34 21 S	253 33	18.4 E	......	......	+0.8	+0.8	+0.8	.....	.....	.....	.....	.....	.....
21	34 52 S	254 12	18.5 E	......	......	+0.7	+0.7	+0.6	.....	.....	.....	.....	.....	.....
21	35 03 S	254 23	......	45.3 S	.282	.....	.....	.....	−0.3	−0.3	−0.2	+3	−4	+1
21	35 41 S	255 06	18.8 E	......	......	+0.5	+0.5	+0.5	.....	.....	.....	.....	.....	.....
22	37 12 S	256 05	19.1 E	......	......	0.0	−0.1	+0.2	.....	.....	.....	.....	.....	.....
23	38 29 S	256 54	......	48.4 S	.275	.....	.....	.....	−0.8	−0.6	−0.2	+2	−4	0
23	38 58 S	257 30	19.8 E	......	......	−0.2	−0.5	0.0	.....	.....	.....	.....	.....	.....
24	39 44 S	258 44	20.9 E	......	......	+0.4	+0.2	+0.6	.....	.....	.....	.....	.....	.....
26	40 22 S	262 25	21.5 E	......	......	+0.1	+0.3	+0.7	.....	.....	.....	.....	.....	.....
27	39 46 S	264 01	......	47.0 S	.274	.....	.....	.....	−0.7	−0.6	0.0	+3	−2	0
27	39 29 S	264 28	21.2 E	......	......	+0.1	+0.1	+0.7	.....	.....	.....	.....	.....	.....
28	38 39 S	265 33	20.2 E	......	......	−0.5	−0.2	+0.1	.....	.....	.....	.....	.....	.....
28	37 57 S	266 12	20.5 E	......	......	+0.1	+0.3	+0.7	.....	.....	.....	.....	.....	.....
29	36 52 S	266 49	......	43.3 S	.274	.....	.....	.....	−1.0	−0.8	−0.4	+1	−3	−1
29	36 04 S	267 15	19.7 E	......	......	0.0	+0.3	+0.6	.....	.....	.....	.....	.....	.....
30	34 48 S	268 00	19.1 E	......	......	−0.1	+0.3	+0.6	.....	.....	.....	.....	.....	.....
30	33 58 S	268 37	18.5 E	......	......	−0.3	+0.1	+0.5	.....	.....	.....	.....	.....	.....
31	32 38 S	269 50	18.0 E	......	......	−0.1	+0.2	+0.6	.....	.....	.....	.....	.....	.....
31	32 33 S	269 58	......	37.4 S	.277	.....	.....	.....	−0.4	−0.3	−0.3	+3	−1	+2
1929														
n. 1	32 13 S	270 47	17.4 E	......	......	−0.4	−0.2	+0.3	.....	.....	.....	.....	.....	.....
2	31 53 S	271 13	......	36.1 S	.277	.....	.....	.....	−0.6	−0.7	−0.5	+4	−1	+2
3	31 54 S	271 56	17.9 E	......	......	+0.5	+0.6	+1.0	.....	.....	.....	.....	.....	.....
4	31 49 S	272 33	......	35.3 S	.274	.....	.....	.....	−0.4	−0.6	−0.2	+2	−3	0
4	31 35 S	272 58	17.6 E	......	......	+0.4	+0.6	+0.9	.....	.....	.....	.....	.....	.....
5	30 36 S	273 42	16.7 E	......	......	0.0	+0.1	+0.5	.....	.....	.....	.....	.....	.....
6	29 31 S	274 17	16.4 E	......	......	+0.2	+0.6	+0.7	.....	.....	.....	.....	.....	.....
6	29 10 S	274 28	......	31.8 S	.276	.....	.....	.....	−0.9	−0.5	−0.5	+5	−2	+1
6	28 23 S	274 57	15.2 E	......	......	−0.5	−0.2	−0.1	.....	.....	.....	.....	.....	.....
8	25 10 S	277 36	......	24.6 S	.278	.....	.....	.....	−0.5	−0.3	−0.1	+8	−3	+3
8	24 40 S	277 56	13.6 E	......	......	−0.1	+0.1	+0.2	.....	.....	.....	.....	.....	.....
9	23 20 S	278 40	......	21.8 S	.281	.....	.....	.....	−0.9	−0.8	−0.2	+10	−2	+5
10	21 06 S	279 44	12.0 E	......	......	+0.2	+0.1	+0.3	.....	.....	.....	.....	.....	.....
11	19 28 S	280 31	11.2 E	......	......	+0.2	+0.1	+0.3	.....	.....	.....	.....	.....	.....
11	18 53 S	280 46	......	13.1 S	.288	.....	.....	.....	−0.1	−0.1	+0.2	+14	−1	+10
11	18 38 S	280 50	10.8 E	......	......	+0.1	+0.2	+0.3	.....	.....	.....	.....	.....	.....
12	16 09 S	281 31	10.2 E	......	......	+0.5	+0.3	+0.6	.....	.....	.....	.....	.....	.....
13	14 33 S	281 59	9.6 E	......	......	+0.6	+0.2	+0.4	.....	.....	.....	.....	.....	.....
13	14 21 S	282 02	......	4.0 S	.297	.....	.....	.....	+1.0	−0.1	+1.4	+16	+2	+12
13	13 46 S	282 06	9.1 E	......	......	+0.4	0.0	+0.2	.....	.....	.....	.....	.....	.....
14	12 45 S	282 35	8.6 E	......	......	+0.3	+0.1	0.0	.....	.....	.....	.....	.....	.....

Notes on Trip From Balboa, Canal Zone, to Easter Island to Callao, Peru, October 25, 1928 to January 14, 1929

Leaving Balboa at noon October 25, the *Carnegie* had over 24 hours of fair wind before facing two weeks of head-winds, heavy rains, squally weather, tacking back and forth, and running the engine in an attempt to get away from the Gulf of Panama. The course stood southward for five days, then northwest for three days, with no change of wind. This made it apparent that the engine and fore-and-aft sails should have to be used on a long tack to the south in an effort to win past the coast of Ecuador, south of the Equator, into the region of the southeast trade-winds before way westward could be made. So the route was changed to go south of the Galapagos Islands instead of north. Malpelo Island was sighted on the tack to the north and was again passed near-by on the long tack to the southward. This island is an isolated, barren rock, one mile long and 846 feet high. There was more rain during these first two weeks than during all the preceding five months of Cruise VII. The engine operated well except for two days' delay due to a burnt-out bearing in one connecting rod. Before clearing the coast and getting a favorable change of wind for sailing the gasoline supply became very low, account being taken of requirements for the three months before a new supply could be obtained.

The delay in the Gulf of Panama gave splendid opportunity for securing a number of ocean-stations in this interesting region. Salinities of surface-water were very low due to the enormous supply of fresh water poured out by the rivers emptying into the Gulf and from the heavy rainfalls. With the shift of wind November 8 from southwest to south, the engine could be shut down, the vessel proceeding westward under sail.

While occupying the ocean-station on November 3, the oscillator used with the sonic depth-finder to measure depths failed to operate due to some short-circuit in the coils. This was a great handicap, since it now became necessary to send the bottom-sampler down on the piano wire first in order to determine the depth before lowering the water-bottles and thermometers. At station No. 40, about 100 miles west of the Ecuadorean coast in latitude 1°32′ south and longitude 82°16′ west, it was not planned to secure a bottom-sample but to send the water-bottles and thermometers down to 3,000 meters as the chart gave the depth at about 3,300

meters. After 1,600 meters had been lowered and another water-bottle was being attached the Chief Engineer, at the winch-controls, stated that he believed the wire had touched bottom since the reel had slowed down very definitely. Upon hauling the wire and bottles up, ten meters of wire were found to be tangled around the bottom bottle and lead weights, giving a depth of 1,515 meters. A bottom-sampler sent down at once on the piano wire reached bottom at 1,454 meters and brought up a small sample of black rock fragments with some globigerina-ooze. This new mountain ridge thus revealed was named "*Carnegie* Ridge." It rises about 1,800 meters above the general level of the ocean-floor in its vicinity.

Since the microphones were still in good order, some means was sought to make a noise in the water which might serve to return an echo from the bottom, the time-interval to be measured by a stop-watch. After considering several expedients, for example, making up a few small bombs with some powder carried for use in the life-line gun, it was suggested to the Chief Engineer to devise a shotgun-method of firing shells under water out of a 20-foot length ot brass pipe. Thus use might be made of the large stock of shotgun shells supplied by the Smithsonian Institution for use in securing specimens of land birds from isolated islands. Within a short time the pipe was fitted with a shell-holder at one end just long enough to cover the shell and a firing-pin was constructed to be operated by hand at the other end. With this device the operator stands on the main deck, starboard side, opposite the microphones, leaning over the rail holding the long pipe, with the shotgun shell in its holder, about two feet under water. When the observer at the microphones blows the whistle, the operator releases the firing-pin and it slides down the tube striking and exploding the shell. This operation is repeated once and at times twice. Very often the observer hears and records the second echo. The accuracy of this method is rated as ± 200 meters, and by comparison with seven depths as determined with unprotected thermometers calibrated for pressure the shotgun-method gave depths about 200 meters too shallow. On occasions the agreement was remarkable. With this device soundings were obtained twice or more daily during the remainder of the cruise from November 15 to Callao. When sounding in 300 meters near the coast seven echoes were heard, and the interval between the shot and the fifth echo was measured.

Although now in the region of the Equator, the temperature of

the air was anything but tropical, ranging from 20° C to 24° C. The following three months were featured by excellent weather, light winds, cool temperature, very little rain or fog, and only one gale which continued for six hours. The temperature never exceeded 24° C and was as low as 15° for only one or two days while the vessel was in the region of 40° south latitude.

Although the *Carnegie* passed close to the south side of the various islands in the Galapagos group, no stop was made because of the delay in leaving the Gulf of Panama. In order to make up for some of this delay the loop to Easter Island was shortened by about ten days, with no appreciable loss in the scientific data secured since it was possible to follow previous tracks on the revised loop.

The good weather experienced gave splendid opportunity to observe the flights of pilot-balloons, using the new theodolite supplied at Balboa by the United States Navy Department. Practically daily flights were observed; on occasions the balloon could be followed for over one hour before it disappeared, the average being about 20 to 30 minutes. With winds of force 5 Beaufort scale, the balloon would disappear in 13 minutes. Two balloons tied together gave better results. The resulting determinations of the velocities and directions were from sea-level up to a height of from two to six miles.

The magnetic and electric program was carried out regularly, the good weather and moderate sea giving excellent results. A paper (see pp. 31-34) on the secular changes in the magnetic elements in the North Atlantic Ocean, based on the *Carnegie* results of 1909 to 1928, was prepared for publication, thus making available to hydrographers the latest information as to these values.

The securing of the bottom-samples was made a regular part of the ocean-station program. Twenty-three samples were secured between Balboa and Callao, being chiefly red clay, blue mud, globigerina- and radiolaria-ooze. A separate report will be made regarding these samples, and the methods and equipment used.

On December 6 Easter Island was reached and six days were spent at anchor in the open roadstead of Cook Bay. On three days atmospheric-electric observations were made on shore simultaneously with observations on board, and for 13 hours continuous observations were made of the magnetic elements on shore.

On December 12 all work had been completed, the equipment was all on board, and plans for a picnic and feast with the natives on

shore had been made when the manila anchor-cable parted, causing the loss of the heavy starboard anchor; the rope had worn through on the hard-coral sandy bottom, the wind being fairly strong all the time. This happened about 10^h fortunately when all were on board and in daylight. The lighter port anchor was let go at once but it dragged. Rather than risk the vessel in such close proximity to the rocks without sufficient anchors it was decided to sail and word was sent ashore to send out the supply of fresh meat. In the meantime the vessel stood out to sea and back again under easy sail and engine-power. By three o'clock in the afternoon, after all arrangements had been completed and supplies had been brought on board, sail was set for Callao.

Manager Edmunds of the ranch at Easter Island, to whom the party is indebted for many kindnesses, was expecting the yearly visit of a supply-steamer any day and had assembled the live cattle and sheep which he was to ship to Chile. The radio here served well in bringing an answer to a message to the office at Washington asking that the company headquarters at Valparaiso be cabled as to when the steamer was leaving for Easter Island. Despite adverse radio conditions a reply was received and delivered the night previous to departure to the effect that the steamer *Antarctico* planned to sail from Valparaiso late in December. Three weeks later, on January 4, 1929, 1,200 miles east of Easter Island, shortly after dark the small steamer *Antarctico* stopped just astern of us. She had left Valparaiso, December 29, and Juan Fernandez, or Robinson Crusoe Island, January 1. Following ten minutes of conversation giving news of Easter Island, we sailed away on our respective courses.

After leaving Easter Island the *Carnegie* was driven 300 miles out of her course to the south by continuous head-winds. The vessel reached 40°.5 south latitude before it was possible to head up on the course entering the southeast trade-wind region on January 5, the day after greeting the *Antarctico*. Steady progress was then made until reaching Callao on January 14.

On January 8 the shotgun was out of order for the morning sounding at 8^h. At 10^h30^m repairs had been made and a sounding gave a depth of 1,445 meters as against a depth of 4,000 meters the previous evening. At noon the depth was 1,186 meters, so orders were given to heave to for a wire-sounding and bottom-sample. A water-bottle, with protected and unprotected thermometers, was sent down also. The wire-angle was 12° which gave

a depth of 1,188 meters. The thermometer gave a depth of 1,168 meters, thus making a close agreement between all three methods. The bottom-sampler brought up an excellent sample of greyish white globigerina-ooze. Thus a new ridge was found to be about 10 miles across and 3,000 meters higher than the surrounding ocean-bed. Soundings were made at intervals of two hours during the afternoon. At 15^h, three miles after the vessel had left the position of the ocean-station, the depth was 1,260 meters; at 16^h, nine miles distant, it was 2,751 meters; at 18^h, 20 miles distant, it was 3,620 meters; and at 20^h, 32 miles distant, it was 4,115 meters. Thus in a distance of 32 miles the depth changed from 1,168 meters to 4,115 meters. Ten miles was the distance run between the first sounding of 1,445 meters (25° 03′.2 south, 82° 20′.0 west) and the sounding of 1,260 meters (24° 54′.0 south, 82° 13′.0 west) before the depth began to increase.

This ridge, named "Merriam Ridge" in honor of the President of the Carnegie Institution of Washington, Dr. John C. Merriam, is probably an extension to the northwestward of the peaks terminating in the islands of San Felix and San Ambrosio, 140 miles to the southeast. Time and the limitations of maneuvering a sailing vessel did not permit more exploration in this region.

The last five days of the cruise were featured by unusually cloudy weather, so that the program of declination-observations twice daily was not possible. The temperature of the surface-water dropped from 21°.5 to 19° C, when the vessel was 75 miles southwest of Callao, and remained at 19° until arrival. The drop was sudden indicating entry into the cold Humboldt or Peruvian Current which flows northward as far as Ecuador.

The vessel's position was determined by star-sights early in the morning of January 14 on Regal and Arcturus, seen for brief moments through rapidly moving clouds. Course was then set for the north end of San Lorenzo Island, off Callao, and for over 50 miles this course was not changed, bringing the vessel to within one mile of the desired point at two o'clock in the afternoon. The *Carnegie* then proceeded under engine-power and was anchored in Callao Harbor a few hours later.

The radio conditions were difficult during the better part of the last two months. The indications were that the difficulty might be caused by local conditions of the general region traversed; whether this is a permanent condition of the region or only a temporary one is an interesting question.

During the portion of the cruise from Balboa to Callao the following observations were made: 96 declination, 34 inclination and horizontal-intensity, and 36 ocean and tow-net stations; 143 sonic depths; 8 atmospheric-electric runs of 24 hours; 44 pilot-balloon flights; 12 series of evaporation-measurements; 50 days of complete photographic potential-gradient records; 43 biological collections; 23 bottom-samples; and regular continuous records of thermographs and baragraphs. Observing conditions were excellent during the entire time with the exception of only one or two days.

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PRELIMINARY VALUES OF THE ANNUAL CHANGES OF THE MAGNETIC ELEMENTS IN THE NORTH ATLANTIC OCEAN, AS DETERMINED FROM THE *CARNEGIE* RESULTS, 1909-1928

By J. P. Ault

The following table contains the average annual-change values of the magnetic elements for the North Atlantic Ocean, as deduced from the observations on the *Carnegie*, 1909-1928. Various stations in the vicinity of intersections of Cruise VII, 1928, with previous tracks have been utilized. The 1928 values are not final, but the small corrections to be made at the completion of the cruise will not change the annual-change values given herein. The method used was the same as indicated on page 185, Volume V, "Researches of the Department of Terrestrial Magnetism," use being made of the United States Hydrographic Office magnetic charts for 1925. The observations have not been corrected for diurnal variations since corrections for these are in general negligible for the times of observation on board the *Carnegie*.

The annual changes for the declination and inclination are referred invariably to the north-seeking end of the magnetic needle. Thus 9′ E means that the north-seeking end of the compass moved toward the east at the average annual-rate of 9′ during the period shown in the third column of the tables; 6′ S means that the north-seeking end of the dip needle moved upwards at the average annual rate of 6′ during the period shown in the third column. The progressive annual-change, or variation in the annual change with time, is given for many regions where the *Carnegie* has crossed more than twice. The localities have been arranged in accordance with descreasing northerly latitude.

TABLE 1—*Average annual-changes for the North Atlantic Ocean*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		years	′	′	c.g.s.		
63.8 N	347.5	1914.6–1928.5	13.9	14 E	......	....	7	3
		1914.6–1928.5	13.9	......	1 N	−.0003	4	2
62.3 N	353.9	1914.5–1928.5	14.0	......	1 N	−.0001	3	1
		1914.5–1928.5	14.0	11 E	......	....	4	4
61.4 N	331.6	1914.7–1928.6	13.9	11 E	......	....	2	4
62.0 N	334.6	1914.7–1928.6	13.9	......	1 S	.0000	3	1
58.6 N	323.6	1914.7–1928.6	13.9	11 E	......	....	5	4
		1914.7–1928.6	13.9	......	2 S	−.0002	3	2
58.2 N	316.8	1914.7–1928.6	13.9	9 E	......	....	4	3
58.0 N	314.8	1914.7–1928.6	13.9	......	1 S	.0000	3	1
52.9 N	309.8	1914.7–1928.6	13.9	7 E	......	....	2	2
53.4 N	310.4	1914.7–1928.6	13.9	......	2 S	.0000	5	1
49.6 N	352.9	1909.8–1913.8	4.0	9 E	......	....	4	3
		1913.8–1928.4	14.6	10 E	......	....	3	2
		1909.8–1928.4	18.6	10 E	......	....	4	2
		1909.8–1913.8	4.0	......	6 S	+.0004	3	3
		1913.8–1928.4	14.6	......	5 N	.0000	3	1
		1909.8–1928.4	18.6	......	1 S	+.0001	3	1
49.1 N	345.7	1909.9–1913.7	3.8	......	7 S	+.0008	3	5
		1909.9–1928.4	18.5	......	1 S	+.0001	3	3
		1913.7–1928.4	14.7	......	0	−.0001	5	3
48.1 N	346.9	1909.8–1913.7	3.9	10 E	......	....	8	9
		1913.7–1928.4	14.7	9 E	......	....	9	4
		1909.8–1928.4	18.6	9 E	......	....	8	4
48.0 N	311.5	1909.8–1914.8	5.0	7 E	......	....	7	8
		1914.8–1928.6	13.8	5 E	......	....	8	4
		1909.8–1928.6	18.8	4 E	......	....	7	4
		1909.8–1914.8	5.0	......	2 S	+.0003	5	3
		1914.8–1928.6	13.8	......	2 S	.0000	3	1
		1909.8–1928.6	18.8	......	2 S	+.0001	3	1
46.2 N	335.8	1913.7–1928.4	14.7	8 E	......	....	5	2
		1913.7–1928.4	14.7	......	2 S	+.0002	4	1
44.5 N	324.0	1913.6–1928.4	14.8	5 E	......	....	4	5
		1914.5–1928.4	13.9	7 E	......	....	2	5
		1913.6–1928.4	14.8	......	2 S	+.0001	2	1
		1914.5–1928.4	13.9	......	4 S	+.0001	2	1
43.6 N	329.9	1913.6–1928.4	14.8	6 E	......	....	3	3
		1913.6–1928.4	14.8	......	4 S	−.0001	4	1
42.8 N	313.5	1914.5–1928.6	14.1	4 E	......	....	3	5
		1914.5–1928.6	14.1	......	5 S	+.0001	3	2
39.6 N	319.3	1913.6–1919.8	6.2	2 E	......	....	6	4
		1919.8–1928.4	8.6	3 E	......	....	4	2
		1913.6–1928.4	14.8	2 E	......	....	6	2
		1913.6–1919.8	6.2	......	1 S	+.0001	3	3
		1919.8–1928.4	8.6	......	2 S	−.0003	3	1
		1913.6–1928.4	14.8	......	2 S	−.0001	3	1

TABLE 1—*Average annual-changes for the North Atlantic Ocean*—Continued

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change: Declination	Average annual-change: Inclination	Average annual-change: Hor. int.	Number of values utilized: First date	Number of values utilized: Second date
°	°		years	′	′	c.g.s.		
38.3 N	297.2	1910.5–1919.8	9.3	10W	......	....	1	5
		1919.8–1928.4	8.6	4W	......	....	5	2
		1914.5–1928.4	13.9	3W	......	....	2	2
		1910.5–1928.4	17.9	7W	......	....	1	2
		1910.5–1914.4	3.9	......	0	−.0010	3	2
		1914.4–1919.8	5.4	......	0	.0000	2	3
		1919.8–1928.4	8.6	......	0	−.0005	3	1
		1910.5–1919.8	9.3	......	0	−.0005	3	3
		1910.5–1928.4	17.9	......	0	−.0005	3	1
		1914.4–1928.4	14.0	......	0	−.0003	2	1
38.1 N	307.1	1910.5–1914.4	3.9	4W	......	....	3	3
		1914.4–1919.8	5.4	5W	......	....	3	4
		1919.8–1928.4	8.6	3W	......	....	4	3
		1910.5–1919.8	9.3	5W	......	....	3	4
		1910.5–1928.4	17.9	4W	......	....	3	3
		1913.9–1919.8	5.9	7W	......	....	4	4
		1913.9–1928.4	14.5	5W	......	....	4	3
		1914.4–1928.4	14.0	4W	......	....	3	3
38.0 N	305.9	1910.5–1913.9	3.4	......	3 S	.0000	3	4
		1914.4–1919.8	5.4	......	1 S	−.0002	3	2
		1919.8–1928.4	8.6	......	1 S	−.0002	2	2
		1910.5–1914.4	3.9	......	4 S	+.0003	3	3
		1910.5–1919.8	9.3	......	2 S	.0000	3	2
		1910.5–1928.4	17.9	......	3 S	−.0001	3	2
		1913.9–1919.8	5.9	......	2 S	.0000	4	2
		1913.9–1928.4	14.5	......	1 S	−.0002	4	2
		1914.4–1928.4	14.0	......	1 S	−.0002	3	2
37.9 N	311.4	1910.5–1914.2	3.7	2 E	......	....	6	6
		1914.2–1919.8	5.6	1W	......	....	6	2
		1919.8–1928.5	8.7	3W	......	....	2	9
		1910.5–1919.8	9.3	0	......	....	6	2
		1910.5–1928.5	18.0	1W	......	....	6	9
		1914.2–1928.5	14.3	2W	......	....	6	9
		1910.5–1914.2	3.7	......	5 S	+.0005	3	4
		1914.2–1919.8	5.6	......	1 S	−.0003	4	2
		1919.8–1928.5	8.7	......	3 S	−.0001	2	3
		1910.5–1919.8	9.3	......	3 S	.0000	3	2
		1910.5–1928.5	18.0	......	3 S	.0000	3	3
		1914.2–1928.5	14.3	......	2 S	−.0002	4	3
37.2 N	289.4	1910.1–1913.9	3.8	7W	......	....	3	4
		1913.9–1919.8	5.9	10W	......	....	4	4
		1919.8–1928.4	8.6	1W	......	....	4	4
		1910.1–1919.8	9.7	9W	......	....	3	4
		1910.1–1928.4	18.3	5W	......	....	3	4
		1913.9–1928.4	14.5	5W	......	....	4	4

TABLE 1—*Average annual-changes for the North Atlantic Ocean*—Continued

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change: Declination	Average annual-change: Inclination	Average annual-change: Hor. int.	Number of values utilized: First date	Number of values utilized: Second date
°	°		*years*	′	′	*c.g.s.*		
		1910.1–1914.6	4.5	......	4 N	−.0010	4	8
		1914.6–1919.1	4.5	......	1 N	−.0003	8	4
		1919.1–1921.8	2.7	......	1 S	−.0006	4	2
		1921.8–1928.4	6.6	......	2 S	−.0007	2	1
37.0 N	287.9	1910.1–1919.1	9.0	......	2 N	−.0005	4	4
		1910.1–1921.8	11.7	......	2 N	−.0006	4	2
		1910.1–1928.4	18.3	......	0	−.0006	4	1
		1914.6–1921.8	7.2	......	5 N	−.0003	8	2
		1914.6–1928.4	13.8	......	1 S	−.0005	8	1
		1919.1–1928.4	9.3	......	2 S	−.0007	4	1
		1910.5–1913.8	3.3	1W	......	....	6	9
		1913.8–1928.6	14.8	3W	......	....	9	4
34.7 N	316.6	1910.5–1928.6	18.1	3W	......	....	6	4
		1910.5–1913.8	3.3	......	3 S	−.0004	4	8
		1913.8–1928.6	14.8	......	3 S	−.0002	8	1
		1910.5–1928.6	18.1	......	3 S	−.0002	4	1
31.2 N	319.6	1913.6–1928.6	15.0	4W	......	....	6	5
		1913.6–1928.6	15.0	......	6 S	−.0001	4	1
		1910.3–1913.6	3.3	11W	......	....	21	7
		1913.6–1928.6	15.0	5W	......	....	7	9
21.9 N	321.0	1910.3–1928.6	18.3	6W	......	....	21	9
		1910.3–1913.6	3.3	......	3 S	−.0003	11	4
		1913.3–1928.6	15.0	......	7 S	+.0002	4	3
		1910.3–1928.6	18.3	......	6 S	+.0001	11	3
		1910.0–1928.7	18.7	10W	......	....	12	8
		1910.6–1928.7	18.1	11W	......	....	6	8
17.1 N	307.4	1910.0–1928.7	18.7	......	3 S	−.0003	5	2
		1910.6–1928.7	18.1	......	2 S	−.0003	3	2
15.4 N	320.4	1910.8–1928.6	17.8	8W	......	....	8	4
		1910.8–1928.6	17.8	......	8 S	+.0002	6	2
12.0 N	316.2	1910.8–1928.7	17.9	12W	......	....	24	10
		1910.8–1928.7	17.9	......	6 S	.0000	12	4
10.4 N	322.2	1910.8–1928.7	17.9	9W	......	....	20	11
		1910.8–1928.7	17.9	......	10 S	+.0001	15	4

[NOTE—A general discussion of the horizontal-intensity results from the various cruises of the *Carnegie* in the North Atlantic has been begun by H. W. Fisk using a method of least-squares adapted to the linear arrangement of stations. Whenever four or more stations are found on 1000 miles of approximately straight or slightly curved track, very good results are obtained. In earlier cruises a much larger number of values was available without unduly extending the line; on Cruise VII the distances between stations are greater. This investigation shows the average annual-change off the northeast corner of South America, east of the Windward Islands, from 10 to 15 gammas *increasing* and not 70 to 90 gammas *decreasing* as indicated on existing charts.—*Ed.*]

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MAGNETIC STORMS OBSERVED BY THE INTERNATIONAL POLAR EXPEDITIONS 1882-1883[1]

By S. Bastamoff

Magnetic disturbances have been under investigation for many years. Recent expeditions, equipped with the most accurate intruments, have disclosed much that is characteristic of these phenomena. However, an examination of the earlier observations of terrestrial magnetism can furnish interesting material and particularly fruitful in this respect are the investigations of 1882-1883, for this was the only instance in the history of such researches that general and special observations were made in a complete network of stations surrounding the north magnetic pole and in its vicinity.

For these stations there were no self-recording magnetographs. The instrumental precision was not great and there were other deficiencies. Still the published material is vast and may serve as an inexhaustible source for conclusions and generalizations. Up to the present time only a partial study of this material has been made and the final results of the gigantic enterprise have not yet been attained, because of the large scale of the undertaking. In the present paper several results are considered which I regard, on the basis of hourly magnetic observations, as belonging preponderantly to the so-called magnetic storms.

In consequence of the fact that the polar expeditions of 1882-1883 were not provided with recording instruments, many of the methods now employed for the determination of magnetic storms can not be used to investigate the data obtained. The selection of quiet days has been made for the results at only a few stations and in fewer still has the classification of magnetic storms been undertaken. The selection, where eye-readings only are available, and the preparation of tables of hourly departures, present enormous difficulties. The result, moreover, is unreliable since the variations between individual readings can not be determined. It is obvious that for this work a convenient method may be substituted—the comparison of the mean and maximum diurnal-amplitudes.

Leyst studied and classified the magnetic storms from this viewpoint in his work "Störung des Erdmagnetismus," in which he has shown that every disturbance produces an increase in the amplitude-variation of the magnetic element and furnishes a basis for determining the disturbance-day. Professor Leyst regards such a day as one during which the amplitude-variation of the magnetic element is in excess of twice the difference of the mean maximum and the mean minimum for the whole time of observation. This

[1]The volume giving the detailed results of this investigation has been published in the Russian language.

method defines a disturbance for each station not with respect to its absolute but to its relative magnitude. It should be remarked that such a definition was suggested as desirable by Mascart during the meeting of the International Polar Commission in 1884.

Later authors, for example, Chree in his "Studies in terrestrial magnetism" (p. 94) revert essentially to the same question. On the basis of his discussion of the observation of the polar expeditions of 1902-1903, he finds that 220 out of 426 were "quieter" days, although he says none of these quiet days of the polar regions would have been considered a quiet day at Kew.

It is obvious that the application of this method will modify the number of magnetic disturbances. An increase in the mean amplitude will add to the quiet days a still larger number of days with insignificant fluctuations as compared with their disturbances; only the largest disturbances will remain as such. For stations which show a considerable disturbance, this method would give a minimum number of storms.

In accordance with this method, I have determined the amplitudes of the mean maxima and minima as shown in Table 1. Here the amplitudes of declination are given in minutes of arc and those of the horizontal and vertical components in gammas (one gamma = 0.00001 C.G.S. unit); the mean values of the horizontal intensity are given also in gammas.

Table 1—*Amplitudes, mean maxima and minima of the three magnetic elements at arctic stations*

Station	Absolute value, horizontal intensity	Mean amplitudes		
		D	H	Z
	γ	′	γ	γ
Sagastyr	9716	67.8	262	343
Neues Land	10744	65.2	335	226
Sodankylä	13396	27.4	236	315
Bossecop	12037	52.6	376	399
Cap Thordsen	8890	87.5	269	416
Jan Mayen	9745	78.5	436	258
Gothaab	9678	79.7	265	...
Fort Conger	5155	183.0	...	...
Kingua Fjord	6379	114.5	210	273
Fort Rae	7650	110.0	414	310
Point Barrow	8940	116.4	258	259

From inspection of the table the inverse relation, for any station, of the declination-amplitude to the value of the horizontal intensity is apparent. The correlation-coefficient is found to be $K = -0.85$, where K is greater that $6E$ and E is the probable error.

This confirms again the fact which Professor Leyst mentioned in his work on the Kursk anomaly. Applying this method I determined the disturbance-days at all the polar stations; the number of such days for declination are given in Table 2.

TABLE 2—*Number of disturbance-days at polar stations*

Station	Number disturbance-days	Station	Number disturbance-days
Sagastyr	47	Gothaab	22
Neues Land	39	Fort Conger	19
Sodankylä	34	Kingua Fjord	24
Bossecop	41	Fort Rae	30
Cap Thordsen	23	Point Barrow	37
Jan Mayen	26		

Disregarding the question of the distribution of such storms with respect to the relation of their intensity to the other geophysical elements, their periodicity, etc., we consider only certain characteristics of terrestrial magnetism in the polar regions.[2] Without

FIG. 1

[2]In the Russian publication an accurate analysis to compare the observation at different stations is given.

attempting further characterization of the stations, we will limit ourselves to adding the chart of Figure 1 showing the geographical distribution of lines of equal magnetic disturbance-days determined from Table 2.

The construction of such a chart is possible only for declination for which element disturbances were observed at all eleven stations. The chart is the period of October 1882 to July 1883. The lines of equal number of disturbance-days I have called "isoturbs." The isoturbs have been drawn by interpolation. However, in regions where the irregular values for stations close together indicated anomalies, these were not used in the interpolation. Thanks to the small number of stations, a simply schematic representation of the isoturbs was possible. The general form of the isoturbs is egg-shaped with the smaller end towards the southwest. The major axis of the curves lies approximately along the west coast of Greenland, that is, in the direction of one of Leyst's "centers" situated in latitude 81° north and longitude 47° west[3]. Thus, in the region of Greenland, the displacement of the maximum zone of polar lights towards the south in years of sunspot-maximum, as determined by Tromhold, appears to have its analogy. The maximum in the polar regions is displaced to the southeast of the geographic pole, that is, in the direction opposite to the region of the magnetic pole.

It should be remarked that isoturb 20 surrounds the points of the north end of the magnetic axis as theoretically determined by Gauss, Weber, and Fritsche, as is evident from an inspection of the chart by Schutz "Der magnetische Pol der Erde" which accompanies the complete publication in Russian.

[3]E. LEYST, On the geographical distribution of normal and anomalous terrestrial magnetism, p. 153.

Berlin, Germany, November 16, 1928

NOTES

(See also pages 54 and 86)

1. *International Meteorological Committee*—Following the invitation extended by Dr. *D. la Cour*, Director of the Danish Meteorological Institute, the next International Conference of Meteorological Directors will be held at Copenhagen during the third week of September 1929. The agenda of the Conference and of its various Commissions are being prepared for distribution two months before the Assembly.

2. *Aeroarctic*—The last session of the United States Congress passed the bill, which was signed in February by the President, under which the United States will contribute $300 annually for five years to Aeroarctic. Arrangements have been completed for the first polar flights during April to May 1930, a contract having been made by the Society for the use of the airship *Graf Zeppelin*. Dr. *F. Nansen* (who will be leader of the scientific work) and Captain *Walther Bruns*, President and General Secretary of the Society, respectively, were in New York and Washington in February to discuss the plans and to make arrangements with the officers of the American Section concerning its organization and cooperation. In addition to observations of geography, aerology, oceanography, biology, and radiotelegraphy, the proposed program includes terrestrial magnetism and atmospheric electricity both on board the airship and at stations on land and ice.

NOTE ON KENNELLY-HEAVISIDE LAYER OBSERVATIONS DURING A MAGNETIC STORM

By L. R. Hafstad and M. A. Tuve

Abstract—Observations of the Kennelly-Heaviside layer by the echo-method during the magnetic disturbance of October 17, 1928, showed an unusually great effective height and a change in echo-pattern. Brief description is given of the method, and of the results obtained on undisturbed days, which are compared with those obtained during the disturbance. The marked changes observed make it clear that further records of this kind will be of great interest.

Observations on the Kennelly-Heaviside layer by the echo-method[1] have been continued at the Department of Terrestrial Magnetism in Washington, D. C. on a more or less routine basis during the fall of 1928. These observations have been made possible, as before, by the interested cooperation of the staff of the Naval Research Laboratory in arranging and transmitting the schedules of special signals from station *NKF*. On October 18 it was learned that a severe magnetic storm was in progress, so a special test was arranged for the observation of the layer during the disturbed period. This note is a report on the observations made at this time.

The method of observation is as follows: A 20-kilowatt radio transmitter operating on 4,435 kilocycles is modulated by means of an unbalanced multivibrator circuit,[2] giving short "peaks" of emitted energy of about 0.0002-second duration, with a signal-frequency of about 20 peaks per second. When these signals are recorded by an oscillograph at the receiving station it is found that under ordinary conditions the received signal consists of two or more peaks separated by intervals of the order of 0.002 second. The interpretation of this result is that the first peak is due to a direct or ground-wave from the transmitter, and the succeeding peaks represent one or more echoes from the ionized layer. From the time required for the signal to travel by the indirect path, assuming the velocity of propagation to be that of light in free space, the height of the "equivalent reflecting-layer" is readily obtained by simple triangulation.

In order to point out clearly the abnormalities which were observed during the magnetic storm, a brief description of the characteristics of the echoes from the ionized layer which are normally observed will be included here, although this work is also being published elsewhere.[3] On two occasions observations have been made over a period of 24 hours, and the records show a marked diurnal-variation both in the effective height of the layer and in the

[1] G. Breit and M. A. Tuve, *Phys. Rev.*, v. 28, 1926 (554-575).

[2] M. A. Tuve and O. Dahl, *Proc. Inst. Radio. Engin.*, v. 16, 1928 (794-798).

[3] L. R. Hafstad and M. A. Tuve, *Proc. Inst. Radio. Engin.*, in press.

"echo-pattern" which is registered at different times of the day for each transmitted pulse.

Figure 1 shows schematically the results of a 24-hour schedule on 4,435 kilocycles as observed October 7-8, 1928. The amplitudes of the separate peaks are indicated very roughly; long lines are three to ten times, short lines approximately equal to, and dots less than, the ground-peak amplitude. The records obtained on September 16-17 were similar both in apparent heights and in observed echo-patterns. The change in echo-pattern is very marked. During the daylight hours from zero to three "reflected peaks" or echoes are normally observed; if more than one, the times are multiples.

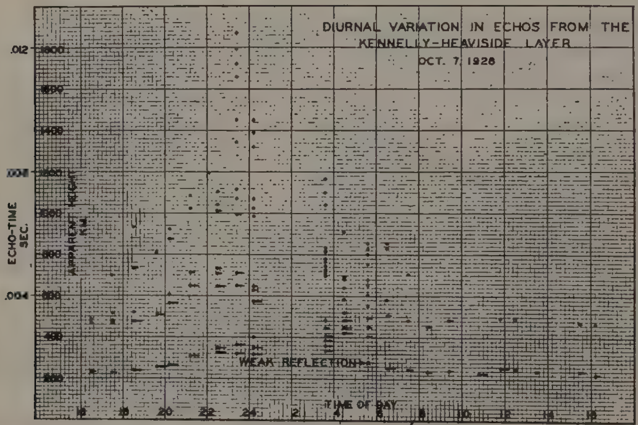


FIG. 1

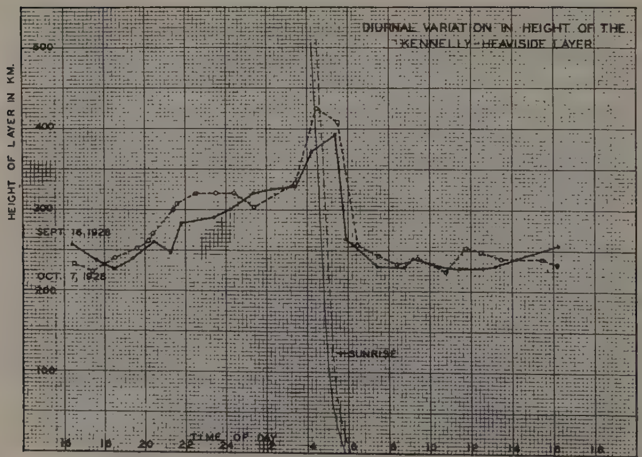


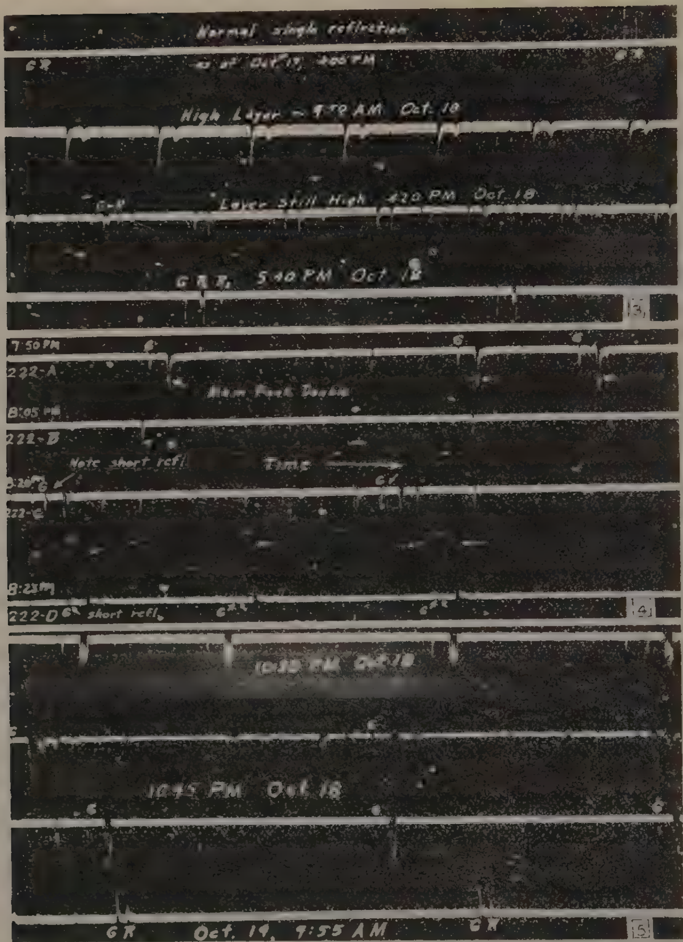
FIG. 2

This suggests multiple reflection between the layer and the Earth. After sunset, reflections from greater and greater apparent heights are observed. They appear in groups at approximately multiple times, although the multiplicity between individual peaks is usually not exact, and for the higher peaks even the grouping is lost. The first peak is usually split into two peaks, unresolved, and in successive groups three or more, with progressively greater separation and often complete resolution. After midnight the scattering increases and the higher reflections disappear, until just before sunrise there is great scattering on the first reflection, and the multiplicity and grouping disappears entirely. Immediately after sunrise the echo-pattern again assumes the normal daylight-form. The weak reflection at the time of sunrise is of interest. Since these heights are not multiples it suggests that a layer at the daytime-height is being formed below that from which the principal reflections occur during the night. Observations on various frequencies should show if there is an actual stratification of the layer. With a multiplicity of echoes the term "height of layer" becomes somewhat ambiguous. However, if the shortest echo-time is taken as a measure of the height (the other "heights" are approximate multiples of this), the diurnal variation is as shown in Figure 2.

The oscillograms shown in Figures 3 to 5 are typical of those obtained during the magnetic storm. The first trace in Figure 3 shows a normal reflection such as was observed at $16^h\ 00^m$ October 17. The second trace shows the high layer observed on the morning of October 18. (In this trace the broadening of the peaks is due to the oscillograph element being cold and hence somewhat over-damped.) The succeeding traces show the variation in the echo-pattern throughout the evening of October 18. Unfortunately it was necessary to discontinue the tests at $22^h\ 45^m$, the transmitter at the Naval Research Laboratory being needed for other schedules. A record obtained the next morning, however, showed that the layer-height had returned to normal. This pattern is shown in the last trace in Figure 5.

The heights of the "equivalent reflecting-layer" as given by these oscillograms are plotted in Figure 6. These being disturbed values, a curve showing the normal variation in the height of the layer is plotted to the same scale for comparison. Above these curves is a copy of the horizontal-intensity magnetogram obtained at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey during the disturbed period. In spite of the meagerness of these data it seems clear that throughout the day of the storm the layer was abnormally high. Whether there was a further rise in the layer during the night is not known, but an observation the next morning showed the normal day value.

Values corresponding to the short reflections as shown in the oscillogram for $20^h\ 20^m$ are also plotted in Figure 6. These reflections are of particular interest for they are the only ones obtained



Figs. 3, 4, 5

from a layer at this height during the autumn of 1928 although such reflections have been observed in earlier work.[4]

Another interesting effect which was observed was the marked change in the form of the night echo-pattern which appeared during the disturbance. Under normal conditions this pattern is as shown in the lower diagram of Figure 7 in which the relative amplitudes of the echoes are plotted against echo-times. Here there is little scattering on the first reflection and the periodicity of the echoes is pronounced. The upper diagram shows the echo-pattern as

[4] G. Breit, M. A. Tuve, and O. Dahl, *Proc. Inst. Radio. Engin.*, v. 16, 1928 (1236-1239); O. Dahl and L. A. Gebhard, *ibidem* (290-296).

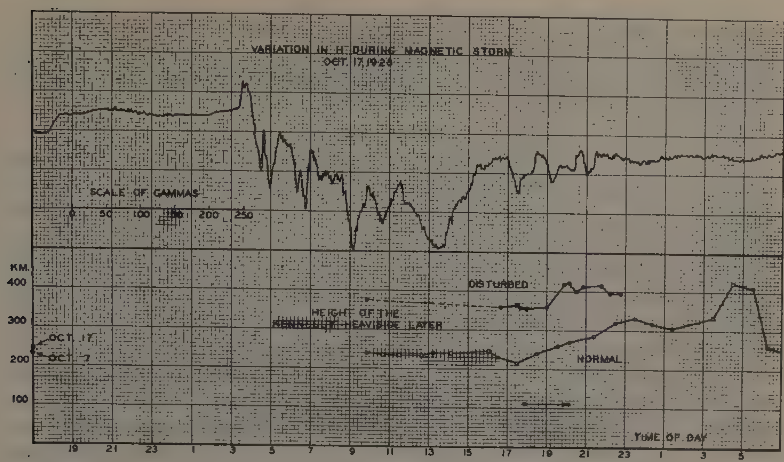


FIG. 6

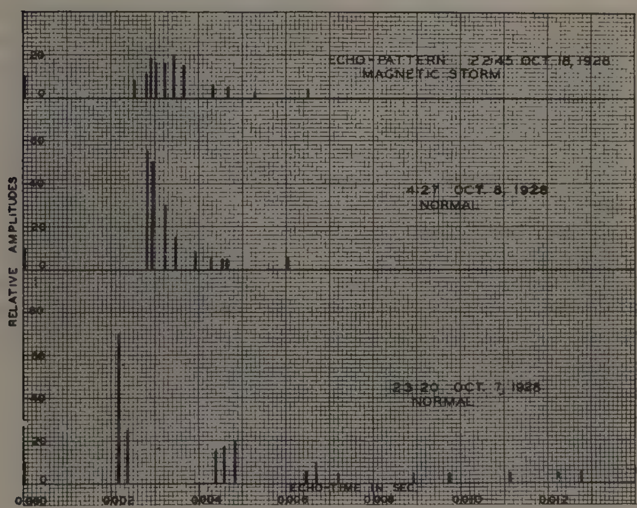


FIG. 7

it appeared at about the same time on the night of the magnetic storm. The signals are much weaker; there is great scattering on the first reflection and no indication of the periodicity which occurs under normal conditions. It is of interest to note that a similar effect is observed under normal conditions just before sunrise. A typical pattern showing this condition is given in the middle diagram of Figure 7. It is difficult to account for the large number of echoes on a single reflection as observed in these two cases on the basis of polarization-effects alone. The fact that the layer-

heights are about equal suggests that the amount of scattering is in some way related to the height, but we feel that the meager experimental information now available hardly justifies a complete discussion of the problem.

In addition to the above effects, which were shown by photographic records, are several chance observations which suggest that the disturbance in radio transmission may precede the magnetic storms. The apparent correlation, however, may be entirely fortuitous.

Under normal conditions the signal from an 8,870-kilocycle transmitter modulated simultaneously with the 4,435-kilocycle transmitter can not be recorded at this Laboratory due to the skip-distance phenomenon and the strong absorption of the ground. On the afternoon of October 17, however, the day *before* the magnetic storm, this signal reached the receiver with great intensity. On only one other occasion this fall has this signal been received and that was shortly before a slight magnetic disturbance on September 19, 1928. Signals of approximately the same frequency have been received erratically in previous years.

Another fact which may be mentioned is that, while an attempt was made to record these signals at the General Electric Laboratory at Schenectady, throughout the fall of 1928, only on October 17, the day preceding the storm, were any records obtained.

While these observational data are meager they do suggest that radio disturbances perhaps precede magnetic storms. Every opportunity will be taken to obtain additional observations for the further investigation of any correlation.

The authors acknowledge with pleasure their great indebtedness to Dr. A. H. Taylor and Messrs. L. A. Gebhard, M. H. Schrenck, and others of the Naval Research Laboratory, and to their colleagues G. Breit, for his continued interest and counsel, and J. A. Fleming, for his enthusiastic support of the work.

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THE UPPER ATMOSPHERE*

By H. B. Maris

Density of the Upper Atmosphere

The density calculations of the following paragraphs are based on the assumptions of diffusion as indicated by Table 3 and temperature-distribution as shown in Figure 7. The calculations for the atmospheric conditions of summer nights are given in detail since it was considered these figures would be the most useful.

The change in atmospheric pressure per centimeter can be calculated for any height Z by the equation

$$P_{Z+1}=P_Z-W_Z=P_Z\,[1/(1+W_Z/P_Z)] \tag{13}$$

or in words P_{Z+1}, the pressure at altitude $(Z+1)$, is equal to the pressure at Z minus the weight of one cubic centimeter of gas at Z. Equation (13) may be written

$$\log P_{Z+1}=\log P_Z-\log\,[1+(W_Z/P_Z)] \tag{14}$$

then $\log P_Z=\log P_0-\Sigma^Z{}_0 \log\,[1+(W_Z/P_Z)]$ but

$$W_Z/P_Z=(W_0/P_0)\,(T_0/T_Z)\,(g_Z/g_0)\,(M_Z/M_0) \tag{15}$$

where W_0, P_C, T_0, g_0, and M_0 represent the weight per cubic centimeter, pressure per square centimeter, temperature, acceleration due to gravity, and molecular weight of any given gas at the initial point, $Z=0$, and W_Z, P_Z, T_Z, g_Z, and M_Z represent the same quantities for the gas at altitude Z. In table 11, calculated values of W_Z/P_Z are given in column 1 and values of $\log\,(1+W_Z/P_Z)$ in column 2 for altitudes from 0 to 100 km. The value of M_Z/M_0 was considered to be unity below the diffusion-levels given in Table 4, column 4, for all gases; at these levels an abrupt change is considered to take place and for greater altitudes (M_Z/M_0) for a given gas is taken as the molecular weight of the given gas divided by 28.95, the molecular weight of air. The change in density is calculated separately for each gas for altitudes greater than 100 km. Table 12 gives values of W/P and $\log\,(1+W/P)$ for altitudes 100, 500, and 1000 km for the condition of summer night based on the assumption of gravity-equilibrium for each gas For these calculations (W_0/P_0), (T_0/T_Z), and (M_Z/M_0) are considered constants; the only variable term in the value of (W_Z/P_Z) is therefore (g_Z/g_0), which may be replaced by (r_0^2/r_Z^2) where r_0 and r_Z are distances from the center of the Earth at sea-level and at the height Z, respectively. The change in (W_Z/P_Z) is then very nearly linear for these altitudes.

*Concluded from this Journal, v. 33, 1928, pp. 233-255. The following corrections in the first section are to be noted: For "K" in the first column of Tables 1, 2, and 3 read "Kr"; for "Table 14" in line nine of p. 249 read "Ta'le 13'

TABLE 11—*Density-factors for air calculated for the temperature-conditions of summer night*

Z	$(W/P)\times 10^6$	Log $(1+W/P)\times 10^7$
km		
0	1.18	5.13
5	1.29	5.61
10	1.50	6.50
15	1.54	6.71
20	1.53	6.63
30	1.48	6.42
40	1.46	6.35
50	1.46	6.33
60	1.45	6.31
80	1.44	6.27
100	1.43	6.22

TABLE 12—*Density-factors for the different gases of the atmosphere calculated for the temperature-conditions of summer night*

Gas	Altitude in kilometers					
	100		500		1000	
	$(W/P)\times 10^6$	Log $(1+W/P)\times 10^7$	$(W/P)\times 10^6$	Log $(1+W/P)$	$(W/P)\times 10^6$	Log $(1+W/P)$
N_2	1.40	6.07	1.24	5.39	1.08	4.67
O_2	1.59	6.89	1.41	6.11	1.22	5.30
A	1.94	8.40	1.72	7.45	1.49	....
CO_2	2.18	9.47	1.93	8.40	1.68	....
Kr	4.11	17.84	3.64	15.82	3.16	....
He_2	0.198	0.860	0.176	0.763	0.152	....
H_2	0.099	0.431	0.088	0.382	0.077	....

The pressure of a gas at any height Z, can be determined by a solution of equation (14). The summation of the right-hand term has been made geometrically in Figure 8 by plotting values of log $(1+W_Z/P_Z)$ against values of Z. The summation of equation (14) from Z_1 to Z_2 is equal to the area under the curve of Figure 8 between Z_1 and Z_2. Partial pressures for the different gases of the atmosphere for the temperature-conditions of summer day (June 12 at 12 A. M.) and night, and winter day and night (December 21) are tabulated in Table 13.

The molecular density, N, or number of molecules per cubic centimeter at altitude Z is given by the equation

$$N=2.66\times 10^{13}\, P_Z\, T_0/T_Z \tag{16}$$

where P_Z the partial pressure is obtained from Table 13, T_0 is equal to 273° and T_Z is obtained from Figure 7. Values of N are tabulated in Table 14.

Many investigators believe there is no appreciable quantity of hydrogen in the atmosphere[19], consequently total density and pressure are given both with and without hydrogen in columns 8 and 9. Values for the mean free-path, λ, of the air-molecules at different altitudes, for the density-conditions of column 8 Table 14, calculated according to the equation

$$\lambda = 0.677/\pi N\sigma = 1.618 \times 10^{14}/N \qquad (17)$$

where N is the number of molecules per cubic centimeter and σ is the molecular diameter are given in Table 15.

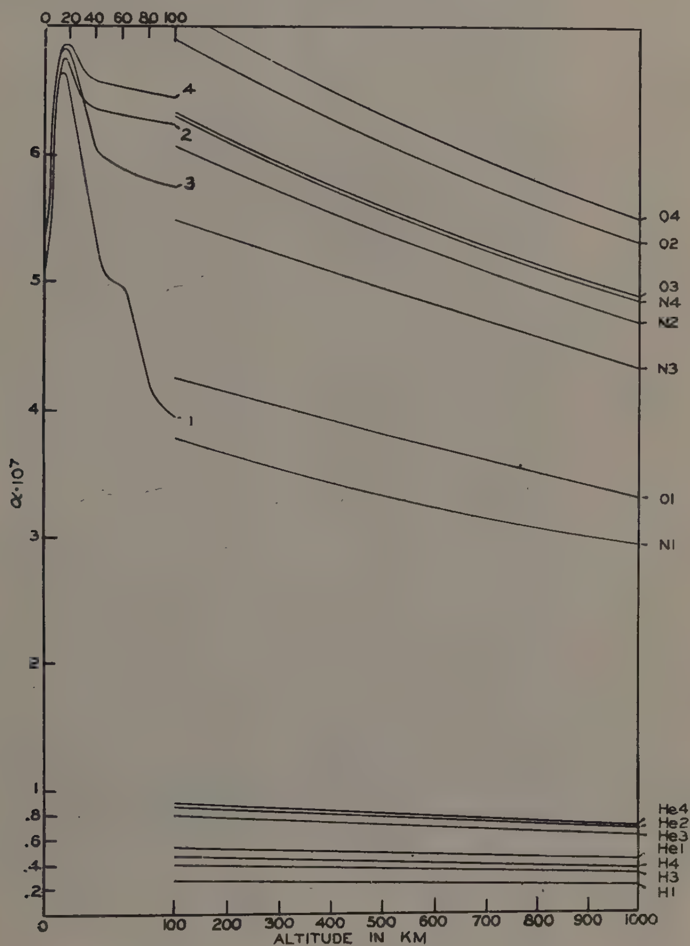

FIG. 8—Values of α plotted against altitude for calculating the densities of the different gases of the air at different altitudes

[19]JEANS, Dynamical theory of gases, p. 340.

TABLE 13—*Pressure in dynes per square centimeter for summer and winter temperature-conditions*

Season, day or night	Z	(1) N_2	(2) O_2	(3) A	(4) CO_2	(5) Kr	(6) He	(7) H_2	Totals (8) Without H_2	(9) With H_2
	km									
Summer day	0	7.91×10^{5}	2.18×10^{5}	9.62×10^{3}	3.04×10^{2}	9.82×10^{1}	4.05×10^{0}	1.14×10^{2}	1.01×10^{6}	1.01×10^{6}
	20	4.62×10^{4}	1.25×10^{4}	5.64×10^{2}	2.01×10^{1}	5.76×10^{0}	2.37×10^{-1}	5.93×10^{0}	5.93×10^{4}	5.93×10^{4}
	40	3.17×10^{3}	8.53×10^{2}	3.86×10^{1}	7.25×10^{0}	3.94×10^{-1}	1.63×10^{-2}	4.08×10^{-1}	4.07×10^{3}	4.07×10^{3}
	60	3.12×10^{2}	8.40×10^{1}	3.81×10^{0}	1.20×10^{-1}	3.88×10^{-2}	1.60×10^{-3}	4.00×10^{-2}	4.00×10^{2}	4.00×10^{2}
	80	3.85×10^{1}	1.04×10^{1}	4.69×10^{-1}	1.48×10^{-2}	4.79×10^{-3}	1.97×10^{-4}	4.93×10^{-3}	4.93×10^{1}	4.93×10^{1}
	100	6.10×10^{0}	1.64×10^{0}	7.42×10^{-2}	2.35×10^{-3}	7.57×10^{-4}	3.13×10^{-5}	7.80×10^{-4}	7.80×10^{0}	7.80×10^{0}
	120	1.03×10^{0}	2.76×10^{-1}	1.25×10^{-2}	3.95×10^{-4}	1.28×10^{-4}	5.26×10^{-6}	1.31×10^{-4}	1.32×10^{0}	1.32×10^{0}
	140	1.77×10^{-1}	4.87×10^{-2}	2.15×10^{-3}	6.81×10^{-5}	2.20×10^{-5}	9.06×10^{-7}	2.27×10^{-5}	2.28×10^{-1}	2.28×10^{-1}
	160	3.15×10^{-2}	8.57×10^{-3}	2.69×10^{-4}	7.48×10^{-6}	1.33×10^{-7}	2.88×10^{-7}	3.98×10^{-6}	4.04×10^{-2}	4.04×10^{-2}
	180	5.78×10^{-3}	1.12×10^{-3}	2.46×10^{-5}	5.30×10^{-7}	8.24×10^{-10}	2.26×10^{-7}	3.51×10^{-6}	6.92×10^{-3}	6.92×10^{-3}
	200	1.10×10^{-3}	1.67×10^{-4}	2.32×10^{-6}	3.81×10^{-8}	5.30×10^{-12}	1.79×10^{-7}	3.11×10^{-6}	1.27×10^{-3}	1.27×10^{-3}
	300	3.27×10^{-7}	1.44×10^{-8}	1.68×10^{-11}	9.30×10^{-14}	8.90×10^{-23}	5.60×10^{-8}	1.72×10^{-6}	3.97×10^{-7}	2.13×10^{-6}
Summer night	0	7.91×10^{5}	2.18×10^{5}	9.62×10^{3}	3.04×10^{2}	9.82×10^{1}	4.05×10^{0}	1.14×10^{2}	1.01×10^{6}	1.01×10^{6}
	20	4.53×10^{4}	1.22×10^{4}	5.52×10^{2}	1.70×10^{1}	5.63×10^{0}	2.32×10^{-1}	5.81×10^{0}	5.81×10^{4}	5.81×10^{4}
	40	2.32×10^{3}	6.24×10^{2}	2.83×10^{1}	8.92×10^{-1}	2.88×10^{-1}	1.19×10^{-2}	2.97×10^{-1}	2.97×10^{3}	2.97×10^{3}
	60	1.26×10^{2}	3.38×10^{1}	1.53×10^{0}	4.83×10^{-2}	1.03×10^{-2}	6.44×10^{-4}	1.62×10^{-2}	1.62×10^{2}	1.62×10^{2}
	80	6.95×10^{0}	1.87×10^{0}	8.47×10^{-2}	2.67×10^{-3}	8.65×10^{-4}	3.57×10^{-5}	8.92×10^{-4}	8.92×10^{0}	8.92×10^{0}
	100	3.93×10^{-1}	1.05×10^{-1}	4.78×10^{-3}	1.51×10^{-4}	4.84×10^{-5}	2.01×10^{-6}	5.03×10^{-5}	5.02×10^{-1}	5.02×10^{-2}
	120	2.81×10^{-2}	5.45×10^{-3}	2.24×10^{-4}	5.16×10^{-6}	3.74×10^{-8}	2.90×10^{-7}	3.22×10^{-6}	3.38×10^{-2}	3.38×10^{-2}
	140	1.76×10^{-3}	2.35×10^{-4}	4.87×10^{-6}	6.87×10^{-8}	1.08×10^{-11}	1.85×10^{-7}	2.70×10^{-6}	2.00×10^{-3}	2.00×10^{-3}
	160	1.11×10^{-4}	1.03×10^{-5}	1.07×10^{-7}	9.36×10^{-10}	3.26×10^{-15}	1.25×10^{-7}	2.22×10^{-6}	1.21×10^{-4}	1.23×10^{-4}
	180	7.36×10^{-6}	4.57×10^{-7}	2.44×10^{-9}	1.31×10^{-11}	1.03×10^{-18}	8.53×10^{-8}	1.83×10^{-6}	7.90×10^{-6}	9.73×10^{-6}
	200	4.82×10^{-7}	2.07×10^{-8}	5.64×10^{-11}	1.87×10^{-13}	3.42×10^{-22}	5.81×10^{-8}	1.51×10^{-6}	5.61×10^{-7}	2.07×10^{-6}
	300	7.30×10^{-13}	5.24×10^{-15}	5.38×10^{-19}	1.62×10^{-22}	2.71×10^{-39}	8.79×10^{-9}	5.81×10^{-7}	8.79×10^{-9}	5.90×10^{-7}

TABLE 13—*Pressure in dynes per square centimeter for summer and winter temperature-conditions—Continued*

Season, day or night	Z	(1) N_2	(2) O_2	(3) A	(4) CO_2	(5) Kr	(6) He	(7) H_2	Totals (8) Without H_2	(9) With H_2
	km									
Winter day	0	7.91×10^{5}	2.18×10^{5}	9.61×10^{3}	3.04×10^{2}	9.82×10^{1}	4.05×10^{0}	1.14×10^{2}	1.01×10^{6}	1.01×10^{6}
	20	4.28×10^{4}	1.15×10^{4}	5.21×10^{2}	1.65×10^{1}	5.32×10^{0}	2.19×10^{-1}	5.48×10^{0}	5.49×10^{4}	5.49×10^{4}
	40	2.24×10^{3}	6.04×10^{2}	2.73×10^{1}	8.63×10^{-1}	2.79×10^{-1}	1.15×10^{-2}	2.88×10^{-1}	2.88×10^{3}	2.88×10^{3}
	60	1.46×10^{2}	3.92×10^{1}	1.77×10^{0}	5.60×10^{-2}	1.80×10^{-2}	7.42×10^{-4}	1.87×10^{-2}	1.87×10^{2}	1.87×10^{2}
	80	9.93×10^{0}	2.67×10^{0}	1.21×10^{-1}	3.82×10^{-3}	1.24×10^{-3}	5.10×10^{-5}	1.27×10^{-3}	1.27×10^{0}	1.27×10^{0}
	100	6.97×10^{-1}	1.88×10^{-1}	8.50×10^{-3}	2.68×10^{-4}	8.61×10^{-5}	3.57×10^{-6}	8.94×10^{-5}	8.94×10^{-1}	6.37×10^{-2}
	120	5.05×10^{-2}	1.32×10^{-2}	7.26×10^{-4}	1.68×10^{-5}	2.00×10^{-7}	2.57×10^{-7}	6.43×10^{-6}	6.37×10^{-2}	4.83×10^{-3}
	140	4.10×10^{-3}	7.31×10^{-4}	2.10×10^{-5}	3.16×10^{-7}	1.13×10^{-10}	1.80×10^{-7}	2.91×10^{-6}	4.83×10^{-3}	3.81×10^{-4}
	160	3.38×10^{-4}	4.12×10^{-5}	5.77×10^{-7}	6.11×10^{-9}	6.62×10^{-14}	1.26×10^{-7}	2.43×10^{-6}	3.79×10^{-4}	3.25×10^{-5}
	180	2.81×10^{-5}	2.32×10^{-6}	1.01×10^{-8}	1.21×10^{-10}	4.05×10^{-17}	8.83×10^{-8}	2.03×10^{-6}	3.05×10^{-5}	4.27×10^{-6}
	200	2.37×10^{-6}	1.35×10^{-7}	4.60×10^{-10}	2.45×10^{-12}	2.58×10^{-20}	6.40×10^{-8}	1.70×10^{-6}	2.59×10^{-6}	7.26×10^{-7}
	300	1.25×10^{-11}	1.18×10^{-13}	1.21×10^{-17}	1.20×10^{-20}	5.14×10^{-36}	1.56×10^{-8}	7.10×10^{-7}	1.56×10^{-8}	3.04×10^{-7}
Winter night	0	7.91×10^{5}	2.18×10^{5}	9.62×10^{3}	3.04×10^{2}	9.82×10^{1}	4.05×10^{0}	1.14×10^{2}	1.01×10^{6}	1.01×10^{6}
	20	3.39×10^{4}	9.15×10^{4}	4.13×10^{2}	1.30×10^{1}	4.22×10^{0}	1.74×10^{-1}	4.35×10^{0}	4.34×10^{4}	4.34×10^{4}
	40	1.56×10^{3}	6.04×10^{2}	1.90×10^{1}	6.01×10^{-1}	1.95×10^{-1}	8.02×10^{-3}	1.08×10^{-1}	2.01×10^{3}	2.01×10^{3}
	60	7.69×10^{1}	3.92×10^{1}	9.38×10^{-1}	2.96×10^{-2}	9.57×10^{-3}	3.94×10^{-4}	9.86×10^{-3}	9.87×10^{1}	9.87×10^{1}
	80	3.87×10^{0}	1.04×10^{0}	4.72×10^{-2}	1.49×10^{-3}	4.82×10^{-4}	1.99×10^{-5}	4.97×10^{-4}	4.97×10^{0}	4.97×10^{0}
	100	1.98×10^{-1}	5.33×10^{-2}	2.41×10^{-3}	7.62×10^{-5}	2.46×10^{-5}	1.02×10^{-6}	2.54×10^{-5}	2.54×10^{-1}	1.30×10^{-2}
	120	1.07×10^{-2}	2.31×10^{-3}	5.72×10^{-5}	1.58×10^{-6}	5.18×10^{-9}	3.10×10^{-7}	3.00×10^{-6}	1.30×10^{-2}	6.93×10^{-4}
	140	6.02×10^{-4}	8.91×10^{-5}	9.86×10^{-7}	1.82×10^{-8}	1.18×10^{-12}	2.07×10^{-7}	2.38×10^{-6}	6.91×10^{-4}	4.00×10^{-5}
	160	3.45×10^{-5}	3.51×10^{-6}	1.74×10^{-8}	2.15×10^{-10}	2.76×10^{-16}	1.38×10^{-7}	1.90×10^{-6}	3.81×10^{-5}	3.73×10^{-6}
	180	2.00×10^{-6}	1.41×10^{-7}	3.15×10^{-10}	2.60×10^{-12}	6.76×10^{-20}	9.25×10^{-8}	1.51×10^{-6}	2.21×10^{-6}	3.94×10^{-6}
	200	1.19×10^{-7}	5.74×10^{-9}	5.82×10^{-12}	3.23×10^{-14}	1.74×10^{-23}	6.21×10^{-8}	1.20×10^{-6}	1.86×10^{-7}	1.37×10^{-6}
	300	1.11×10^{-13}	8.63×10^{-16}	1.78×10^{-20}	1.41×10^{-23}	4.00×10^{-41}	8.73×10^{-9}	3.87×10^{-7}	8.73×10^{-9}	3.94×10^{-7}

TABLE 14—*Molecular densities of gases of the atmosphere for summer and winter temperature-conditions*

Season, day or night	Z	(1) N_2	(2) O_2	(3) A	(4) CO_2	(5) Kr	(6) He	(7) H_2	Totals (8) Without H_2	Totals (9) With H_2
	km									
Summer day	0	2.00×10^{19}	5.38×10^{18}	2.44×10^{17}	7.69×10^{15}	2.49×10^{15}	1.03×10^{14}	2.57×10^{15}	2.56×10^{19}	2.56×10^{19}
	20	1.48×10^{18}	3.99×10^{17}	1.81×10^{16}	5.70×10^{14}	1.85×10^{14}	7.10×10^{12}	1.90×10^{18}	1.90×10^{18}	1.90×10^{18}
	40	8.44×10^{16}	2.27×10^{16}	1.03×10^{15}	3.24×10^{13}	1.05×10^{13}	4.33×10^{11}	1.08×10^{13}	1.08×10^{17}	1.08×10^{17}
	60	7.75×10^{15}	2.08×10^{15}	9.44×10^{13}	2.98×10^{12}	9.64×10^{11}	3.97×10^{10}	9.93×10^{11}	9.92×10^{15}	9.92×10^{15}
	80	8.04×10^{14}	2.16×10^{14}	9.57×10^{12}	3.02×10^{11}	1.00×10^{11}	4.12×10^{9}	1.03×10^{11}	1.03×10^{15}	1.03×10^{15}
	100	1.21×10^{14}	3.25×10^{13}	1.47×10^{12}	4.65×10^{10}	1.50×10^{10}	6.29×10^{8}	1.55×10^{10}	1.55×10^{14}	1.55×10^{14}
	120	2.01×10^{13}	5.38×10^{12}	2.44×10^{11}	7.69×10^{9}	2.49×10^{9}	1.31×10^{8}	2.57×10^{9}	2.57×10^{13}	2.56×10^{13}
	140	3.45×10^{12}	9.29×10^{11}	4.20×10^{10}	1.32×10^{9}	4.29×10^{8}	1.77×10^{7}	4.42×10^{8}	4.42×10^{12}	4.42×10^{12}
	160	6.14×10^{11}	1.48×10^{11}	$5.3\ \times10^{9}$	1.46×10^{8}	2.58×10^{6}	5.61×10^{6}	7.73×10^{7}	7.67×10^{11}	7.67×10^{11}
	180	1.13×10^{11}	2.18×10^{10}	$4.8\ \times10^{8}$	1.03×10^{7}	1.61×10^{4}	4.42×10^{6}	6.84×10^{7}	1.35×10^{11}	1.35×10^{11}
	200	2.15×10^{10}	3.25×10^{9}	$4.5\ \times10^{7}$	$7.5\ \times10^{5}$	1.02×10^{2}	3.48×10^{6}	6.07×10^{7}	2.48×10^{10}	2.48×10^{10}
	300	6.38×10^{6}	2.77×10^{5}	$3.3\ \times10^{2}$	1.8	$1.6\ \times10^{-9}$	1.09×10^{6}	3.35×10^{7}	7.72×10^{6}	4.12×10^{7}
Summer night	0	2.00×10^{19}	5.38×10^{18}	2.44×10^{17}	7.69×10^{15}	2.49×10^{15}	1.03×10^{14}	2.57×10^{15}	2.56×10^{19}	2.65×10^{19}
	20	1.49×10^{18}	4.00×10^{17}	1.81×10^{16}	5.72×10^{14}	1.85×10^{14}	7.62×10^{12}	1.91×10^{14}	1.91×10^{18}	1.91×10^{18}
	40	7.31×10^{16}	1.97×10^{16}	8.91×10^{14}	2.82×10^{13}	9.10×10^{12}	3.75×10^{11}	9.38×10^{12}	9.37×10^{16}	9.37×10^{16}
	60	3.96×10^{15}	1.07×10^{15}	4.83×10^{13}	1.52×10^{12}	4.93×10^{11}	2.03×10^{10}	5.08×10^{11}	5.08×10^{15}	5.08×10^{15}
	80	2.19×10^{14}	5.90×10^{13}	2.67×10^{12}	8.43×10^{10}	2.73×10^{10}	1.42×10^{9}	2.81×10^{10}	2.81×10^{14}	2.81×10^{14}
	100	1.24×10^{13}	3.33×10^{12}	1.51×10^{11}	4.76×10^{9}	1.54×10^{9}	6.34×10^{7}	1.59×10^{9}	1.59×10^{13}	1.59×10^{13}
	120	8.89×10^{11}	1.72×10^{11}	7.10×10^{9}	1.63×10^{8}	1.18×10^{6}	8.63×10^{6}	1.04×10^{8}	1.07×10^{12}	1.07×10^{12}
	140	5.56×10^{10}	7.42×10^{9}	1.54×10^{8}	2.17×10^{6}	3.42×10^{2}	5.85×10^{6}	8.55×10^{7}	6.32×10^{10}	6.33×10^{10}
	160	3.52×10^{9}	3.24×10^{8}	3.40×10^{6}	2.96×10^{4}	1.03×10^{-1}	3.98×10^{6}	7.03×10^{7}	3.84×10^{9}	3.91×10^{9}
	180	2.33×10^{8}	1.45×10^{7}	7.71×10^{4}	4.12×10^{2}	3.26×10^{-3}	2.70×10^{6}	5.79×10^{7}	2.50×10^{8}	3.08×10^{8}
	200	1.53×10^{7}	6.56×10^{5}	2.11×10^{3}	4.90×10^{0}	1.08×10^{-8}	1.83×10^{6}	4.78×10^{7}	1.78×10^{7}	6.56×10^{7}
	300	2.31×10^{1}	1.66×10^{-1}	1.70×10^{-5}	5.15×10^{-9}	8.57×10^{-26}	2.78×10^{5}	1.84×10^{7}	2.78×10^{5}	1.87×10^{7}

TABLE 14—*Molecular densities of gases of the atmosphere for summer and winter temperature-conditions—Continued*

Season, day o night	Z	(1) N_2	(2) O_2	(3) A	(4) CO_2	(5) Kr	(6) He	(7) H_2	Totals (8) Without H_2	(9) With H_2
	km									
Winter day	0	2.09×10^{19}	5.63×10^{18}	2.55×10^{17}	8.05×10^{15}	2.61×10^{15}	1.07×10^{14}	2.69×10^{15}	2.68×10^{19}	2.08×10^{19}
	20	1.44×10^{18}	3.86×10^{17}	1.75×10^{16}	5.52×10^{14}	1.79×10^{14}	7.36×10^{12}	1.84×10^{14}	1.85×10^{18}	1.85×10^{18}
	40	6.71×10^{16}	1.80×10^{16}	8.18×10^{14}	2.58×10^{13}	8.36×10^{12}	3.44×10^{11}	8.61×10^{12}	8.59×10^{16}	8.59×10^{16}
	60	4.28×10^{15}	1.15×10^{15}	5.21×10^{13}	1.64×10^{12}	5.32×10^{11}	2.19×10^{10}	5.49×10^{11}	5.58×10^{15}	5.58×10^{15}
	80	2.89×10^{14}	7.78×10^{13}	3.52×10^{12}	1.11×10^{11}	3.60×10^{10}	1.48×10^{9}	3.71×10^{10}	3.71×10^{14}	3.71×10^{14}
	100	2.02×10^{13}	5.45×10^{12}	2.47×10^{11}	7.78×10^{9}	2.57×10^{9}	1.04×10^{8}	2.59×10^{9}	2.59×10^{13}	2.59×10^{13}
	120	1.46×10^{12}	3.82×10^{11}	2.10×10^{10}	4.85×10^{8}	5.80×10^{6}	7.45×10^{6}	1.86×10^{8}	1.86×10^{12}	1.86×10^{12}
	140	1.19×10^{11}	2.12×10^{10}	6.07×10^{8}	9.16×10^{6}	3.27×10^{3}	5.20×10^{6}	8.43×10^{7}	1.41×10^{11}	1.41×10^{11}
	160	9.80×10^{9}	1.20×10^{9}	1.67×10^{7}	1.77×10^{5}	1.92	3.65×10^{6}	7.02×10^{7}	1.10×10^{10}	1.11×10^{10}
	180	8.15×10^{8}	6.73×10^{7}	4.67×10^{5}	3.50×10^{3}	1.17×10^{-3}	2.56×10^{6}	5.89×10^{7}	8.85×10^{8}	9.44×10^{8}
	200	6.87×10^{7}	3.93×10^{6}	1.33×10^{4}	7.08×10^{1}	7.47×10^{-7}	1.85×10^{6}	4.93×10^{7}	7.45×10^{7}	1.24×10^{8}
	300	3.61×10^{2}	3.42	3.51×10^{-4}	3.46×10^{-7}	1.49×10^{-22}	4.51×10^{5}	2.06×10^{7}	4.51×10^{5}	2.11×10^{7}
Winter night	0	2.09×10^{19}	5.63×10^{18}	2.55×10^{17}	8.05×10^{15}	2.61×10^{15}	1.07×10^{14}	2.69×10^{15}	2.68×10^{19}	2.68×10^{19}
	20	1.15×10^{18}	3.09×10^{17}	1.40×10^{16}	4.42×10^{14}	1.43×10^{14}	5.90×10^{12}	1.47×10^{14}	1.48×10^{18}	1.48×10^{18}
	40	5.09×10^{16}	1.37×10^{16}	6.21×10^{14}	1.96×10^{12}	6.34×10^{12}	2.61×10^{11}	6.53×10^{12}	6.52×10^{16}	6.52×10^{16}
	60	2.51×10^{15}	6.76×10^{14}	3.06×10^{13}	9.66×10^{11}	3.13×10^{11}	1.29×10^{10}	3.18×10^{11}	3.22×10^{15}	3.22×10^{15}
	80	1.36×10^{14}	3.40×10^{13}	1.54×10^{12}	4.85×10^{10}	1.57×10^{10}	6.47×10^{8}	1.62×10^{10}	1.72×10^{14}	1.74×10^{14}
	100	6.47×10^{12}	1.74×10^{12}	7.89×10^{10}	2.49×10^{9}	8.06×10^{8}	3.31×10^{7}	8.30×10^{8}	8.29×10^{12}	8.29×10^{12}
	120	3.48×10^{11}	7.52×10^{10}	1.86×10^{9}	5.15×10^{7}	1.69×10^{5}	1.01×10^{7}	9.75×10^{7}	4.25×10^{11}	4.25×10^{11}
	140	1.96×10^{10}	2.90×10^{9}	3.21×10^{7}	5.93×10^{5}	3.83×10^{1}	6.73×10^{6}	7.76×10^{7}	2.28×10^{10}	2.28×10^{10}
	160	1.12×10^{9}	1.14×10^{8}	5.68×10^{5}	7.00×10^{3}	9.0×10^{-3}	4.50×10^{6}	6.15×10^{7}	1.33×10^{9}	1.39×10^{9}
	180	6.53×10^{7}	4.58×10^{6}	1.03×10^{4}	8.47×10^{1}	2.2×10^{-6}	3.01×10^{6}	4.90×10^{7}	7.29×10^{7}	1.22×10^{8}
	200	3.86×10^{6}	1.87×10^{5}	1.90×10^{2}	1.05	5.7×10^{-10}	2.02×10^{6}	3.92×10^{7}	6.10×10^{6}	4.53×10^{7}
	300	3.61×10^{0}	2.81×10^{-2}	5.80×10^{-7}	4.6×10^{-10}	1.3×10^{-27}	2.26×10^{5}	1.26×10^{7}	2.26×10^{5}	1.28×10^{7}

Table 15—*Mean free-path λ in centimeters*

Z	(1) Summer Day	(2) Summer Night	(3) Winter Day	(4) Winter Night
km				
0	6.32×10^{-6}	6.32×10^{-6}	6.04×10^{-6}	6.04×10^{-6}
20	8.52×10^{-5}	8.48×10^{-5}	8.75×10^{-5}	1.09×10^{-4}
40	1.50×10^{-3}	1.72×10^{-3}	1.88×10^{-3}	2.48×10^{-3}
60	1.63×10^{-2}	3.19×10^{-2}	2.90×10^{-2}	5.02×10^{-2}
80	1.57×10^{-1}	5.76×10^{-1}	4.36×10^{-1}	9.41×10^{-1}
100	1.04	1.02×10^{1}	6.24	1.95
120	6.29	1.51×10^{2}	8.70	3.81×10^{2}
140	3.66×10^{1}	2.56×10^{3}	1.15×10^{3}	7.10×10^{3}
160	2.11×10^{2}	4.21×10^{4}	1.47×10^{4}	1.21×10^{5}
180	1.20×10^{3}	6.47×10^{5}	1.83×10^{5}	2.22×10^{6}
200	6.52×10^{3}	9.09×10^{6}	2.17×10^{6}	2.65×10^{7}
300	2.10×10^{7}	1.67×10^{9}	1.03×10^{9}	2.06×10^{9}
400	1.29×10^{9}	....	....	....

Summary

The following conclusions have been reached from this discussion. The gases of the air are uniformly mixed below a height of roughly 100 km; above 150 km each gas is in equilibrium with its own partial pressure; and between these two heights there is for each gas a transition from uniform mixture with the air to equilibrium with its own partial pressure at a height which depends on the temperature and previous wind-currents of the atmosphere, but which averages about 110 km. The temperature of the upper atmosphere varies with the hour of the day and with the season of the year, and probably increases continually with increasing altitude. The amount of this variation depends on the absorption-coefficient of the upper atmosphere for radiation of different wave-lengths principally in the ultraviolet and infra-red. Estimates based on known coefficients predict a temperature-change of 140° C between day and night during the summer and 30°C during the winter above 60 km. Density-tables show roughly one hundred-thousandth of the densities given by classical calculations above 200 km. It is predicted that above 300 km densities can not be calculated by the ordinary equations for gas-density because we would not expect the molecules at the outer boundary of the atmosphere absorbing light to be in thermal equilibrium. Since these conclusions and density-calculations are such a radical departure from the classical conception of the air, that is, gravity-equilibrium from sea-level up and uniform temperature above 12 km, it would be well to review briefly the assumptions made during the discussion.

The diffusion-calculations are based on the assumption of

0° C as the average temperature and 5×10^5 seconds or roughly 6 days as the average time through which diffusion has progressed. Radiation-equilibrium temperature-calculations are based on the assumption of ultraviolet absorption of four per cent of the Sun's radiation by intense absorption-bands; infra-red absorption bands of wave-lengths greater than 20 μ comparable with the bands in the region 2 to 20 μ; and the validity of Kirchoff's law for gases under very low pressures and temperatures. In making the calculations, coefficients of absorption are assumed to be independent of pressure; absorption in an extended layer is considered as absorption in a plane; all radiation from the Earth is assumed to be vertical, and the radiation outward through the atmosphere is assumed to be that of a black body. Of these assumptions all but the last would lead to very small errors, since for a change in absorption there is generally a compensating change in radiation, and the temperature of radiation-equilibrium is unaltered.

We would expect changes in cloudiness and in the humidity of the air to result in great changes in the radiation through the outer atmosphere since clouds reflect 50 per cent of the sunlight falling on them from above and probably an even greater part of the Earth radiation striking them from below. However, since the cloud itself is at a temperature much above that of the outer atmosphere, we would expect only a slight change in the radiation by the outer atmosphere. That is, on a clear night the Earth is cooled by radiation; on a cloudy night, the Earth is not cooled so much but the cloud itself is cooled and a much larger percentage of the radiation from the clouds is in wave-lengths absorbed by the outer atmosphere, therefore we would expect no radical change in the temperature of the upper strata at night because of clouds even though there is a decided change in the total radiation escaping from the Earth. That is, radiation which passes through the air unabsorbed on a clear night does not affect the temperature of the upper atmosphere and consequently is not missed when it is reflected back during cloudy weather. Nevertheless, it is probable that the greatest source of error in the calculation is to be found in the assumption that the radiation outward from the Earth is black-body radiation.

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NOTES

(See also pages 38 and 86)

3. *Nucleation-Counts on Byrd Antarctic Expedition*—*Frank T. Davies*, physicist with the Byrd Antarctic Expedition, made occasional nucleation-counts over the oceans during the journey of the ship *City of New York* in the Caribbean Sea and Pacific Ocean via the Panama Canal to Dunedin, New Zealand, and thence to the base-station of the Expedition. He reports that in the Caribbean Sea the observations indicated about 2,000 particles per cc. During long fine spells of weather between Balboa and Tahiti the counts were between 4,000 and 5,000 per cc with one higher than 8,000, and during the latter part of October, when there were a few showers before arrival at Tahiti, the counts were about 2,000, with a minimum of 1,000 about two hours before a rain squall. The results of observations subsequent to those at Tahiti have not yet been reported.

4. *Appropriation for investigating atmospheric phenomena*—There has been appropriated for the United States Weather Bureau the sum of $850,000 for the investigation of the upper atmosphere and for the meteorological service in connection with the control of commercial air-ways.

5. *Magneto-chronograph*—The magneto-chronograph, designed and constructed by *H. E. McComb* of the U. S. Coast and Geodetic Survey and *C. Huff* of the Department of Terrestrial Magnetism through cooperation of the two organizations, as exhibited at the Exhibition Representing Results of Research Activities of the Carnegie Institution of Washington on December 15-17, 1928, has been used in an extensive series of investigations at the Cheltenham Magnetic Observatory in the determination of the moment of inertia of a magnetometer-magnet, estimation of personal equation in eye-and-ear readings, and preliminary tests made to determine its efficiency as a relative absolute magnetometer. The results of the investigation will be forwarded for publication in the next issue of this JOURNAL.

6. *Cruise VII of the Carnegie*—The *Carnegie* arrived at Callao, Peru, January 14; the preliminary notes and results are published in this number of the JOURNAL. After comparisons of instruments with the standards of the Huancayo Magnetic Observatory and the other shore observations and necessary vessel-repairs, the *Carnegie* sailed for Papeete, Tahiti, February 5. Wireless communication with the vessel was excellent during February, messages being received almost daily. Fine weather had prevailed to the time of the radiogram sent February 28, when the vessel was in latitude 14°.9 south and longitude 126°.2 west.

7. *Mexican Astronomical and Geophysical Society*—In September 1928 there was formed in Mexico City the Sociedad de Estudios Astronómicos y Geofísicos for the purpose of stimulating persons engaged in scientific work and for keeping them informed of the latest investigations and discoveries in other countries. The Society is divided into five sections, namely, Astronomy, Geodesy, Geophysics, Geography, Mathematics, and Meteorology. The principal organ of the Society is called the Revista de la Sociedad de Estudios Astronómicos y Geofísicos and it is expected that five numbers will appear during the present year. The first issue (January, 1929) contains two principal articles of which one written by Sr. Rosendo O. Sandoval, is devoted to a discussion of the theory of terrestrial magnetism and an account of magnetic observations in Mexico.

OBSERVATIONS ON IONIC CONTENT AT ABERDEEN

By A. E. M. Geddes, O.B.E., M.A., D.Sc.

"Information as to diurnal variation is very scanty except in the case of potential gradient." This statement is contained in a paper by Dr. C. Chree in which he was discussing the atmospheric electrical elements.[1] The following paper deals briefly with the results of a short investigation undertaken with the object of determining how this lack of information might be remedied to a certain extent. The space of time over which the observations were made was short and the results by themselves could not be considered conclusive. But when taken in conjunction with values already well established, they may serve to act as a guide, pending a more rigorous investigation.

Apparatus—The observations, which were carried out during the month of September 1928, were made three times daily whenever possible, (1) between 8^h and 9^h, (2) between 13^h and 14^h, (3) between 17^h and 18^h, all G. M. T. As recorder of the ions an Ebert ion-counter was used. This particular instrument is one of the type with vertical condenser and electroscope. The calibration was supplied by the makers, Günther & Tegetmeyer. The capacity of the system is given as 9.32 cm, while the diameters of the outer and inner cylinders of the condenser are 3 cm and 0.5 cm, respectively. The fan attached to the instrument is able to pull 0.8996 cubic meter of air at ordinary temperature and pressure through the system in 575 seconds. A Zamboni dry-pile serves to charge the condenser. The apparatus was set up on a small lawn near tall ash trees and inside a wide-meshed netting-wire cage. The dimensions of the cage are, height 3 feet 9 inches, width 3 feet 8 inches, length from front to back 3 feet 4 inches. The top of the cone of the ion-counter was 3 feet 2 inches above the ground. Such an arrangement proved to be very convenient as it could be transported easily and set up in any desired position.

Wet- and dry-bulb thermometers were also installed near in order to test whether the relative humidity had any marked effect on the ion-concentration.

The mobility of the ions tested—In order that, as far as possible, only "small" ions might be counted, comparatively small voltages were used, that is, voltages from 100 up to 180 volts. On the assumption that turbulence may be ignored, Gerdien has shown that the velocity "u" with which the air-stream should flow through a cylindrical condenser with outer and inner radii r_1 and r_2 and length l in order that all ions of mobility K may be caught is given by the formula

$$u \leq 2KlV/(r_1^2-r_2^2)\log_e(r_1/r_2)$$

where V is the voltage between the inner and outer cylinders.

If the formula is valid then in our particular case with $u=220$ cm/sec, $l=17.5$ cm,* $r_1=1.5$ cm, $r_2=0.25$ cm, the value of V may be lowered to 19.0 volts and all the positive ions (for which the mobility is 1.3 cm/sec in a field one v/cm) will be caught. For the negative ions with mobility 1.5 cm/sec the voltage may be lowered to 16.4 volts. On the other hand, if one considers the highest

[1] *Phys. Soc. Proc.*, v. 37, 1924-25 (5D).

*The central rod is bent, the length of the three parts vertical, horizontal, and vertical are 12 cm, 3.8 cm, and 1.7 cm, respectively.

voltage used, namely, 180 volts, then *all* ions having a mobility as low as 0.13 cm/sec would be caught, and a voltage of 100 volts, the lowest used, would still succeed in catching some ions with mobility 0.1 cm/sec.

Now the mobility of the "large" ions is in the neighbourhood of 0.0003 cm/sec, so that it appears that the number of these likely to be caught would be small, and their effect negligible. The "intermediate" ions[1] discovered by Professor J. A. Pollock, have been found to possess a mobility ranging from 0.1 to 0.01 cm/sec. In the present experiments, therefore, a certain number of these would be caught, if such ions were present in the air. As the voltages employed were not large enough to give saturation for this type of ion, the higher voltages ought to give therefore, on the average, a bigger ion-concentration than the lower. In order to test whether this is the case or not, three ranges of voltage have been investigated, namely, 100 to 130, 130 to 160, and 160 to 180 volts. The evidence of the presence of intermediate ions is not very conclusive. If the afternoon values be taken, one finds for the three ranges

n_+	630	835	666
n_-	608	737	533

The number of observations taken at voltages over 160 was only two, and therefore but little weight can be attached to the third set of values. The other two sets seem to indicate the presence of intermediate ions. The middle set, however, includes the results of several days on which visibility was high and on which ion-concentration was much above the normal, while the other set had days on which the values were much below the normal. If due account be taken of these points by discounting the abnormal days, the numbers for both sets found on days when the meteorological conditions were apparently normal, approach quite close to one another, being for n_+, 731 and 750, and for n_-, 750 and 700, respectively. In the present investigation it has been assumed, therefore, that the ions counted were all of the "small" ion type.

Method of observation—After the condenser, the outside of which was earthed, had been charged, the fan was allowed to run for a period with the electrical system shut off. Then followed a period when the fan and the condenser system were in conjunction, the air being pulled through the condenser. This complete sequence was repeated without recharging the system and the position of the leaves noted at the end of each time. The fan was allowed to run continuously throughout both periods. The whole process was then repeated with the inside of the condenser charged oppositely. As a rule very little fall was observed in the intervals when fan and condenser were shut off from each other, the fall seldom exceeding 0.1 scale-division, while in some instances a slight rise was observed, particularly when the inside was negatively charged.

Simultaneously with the electrical observations, a number of the meteorological elements were also noted. These observations included estimates of the direction and velocity of the wind, the direction of motion, type and amount of cloud, together with the readings of the wet- and dry-bulbs.

[1] *Phil. Mag.*, v. 29, 1915 (636).

Results—The average values of the ionic content, etc. obtained from the observations are given in Table 1.

TABLE 1

Epoch Sep. 1928	Charge			Ions		
	Sign	E.S.U. 10^6cc	Coulomb 10^{16} cc	Sign	Number cc	Ratio +/− q
Forenoon 8^h–9^h	E+ E− E+-E−	.280 .256 .024	.93 .85 .08	n+ n− n+-n−	584 537 47	1.09
Afternoon 13^h–14^h	E+ E− E+-E−	.360 .321 .039	1.20 1.07 .13	n+ n− n+-n−	754 669 85	1.12
Evening 17^h–18^h	E+ E− E+-E−	.265 .239 .026	.88 .80 .09	n+ n− n+-n−	554 500 50	1.11

Here E_+ and E_- give the ionic content. The results are expressed in terms of electrostatic units as is usual in work on this subject, and also in terms of coulombs in accordance with the practice of the Observatories' Year Book of the Meteorological Office. The difference E_+-E_- is the excess of free positive charge carried by small ions.

In Table 1 of the paper by Chree already referred to, the ionic content at Kew for September is about 7 per cent above the normal for the year. At Strelitz it is shown to be about 10 per cent. If then we suppose that the values given in the present Table 1 are above the normal, to about the same extent as those for Kew, our values will have to be reduced slightly in order to give an idea of the probable average annual-values. When this is done, the afternoon positive and negative values for E are *0.337* and *0.300* electrostatic units respectively, giving for n the numbers 705 positive and 625 negative. These afternoon values approach closely the average values over land as given by Chauveau.[2] His numbers are $n_+ = 750$ and $n_- = 630$. Further the average values deduced from the ionic content for a number of stations distributed over the globe are, according to Hess[3], $n_+ = 798$ and $n_- = 650$. On the other hand the averages over sea as given by these same two authorities are $n_+ = 730$, $n_- = 580$ (Chauveau), and $n_+ = 670$, $n_- = 576$ (Hess). The average afternoon values for Aberdeen therefore, approach fairly closely to the average values for land-stations, nearer than to those for sea-stations.

But though there appears to be this agreement among the averages considered above, it must always be borne in mind that stations differ greatly in their average values the one with the other. A reason for the approach of the Aberdeen values towards the average of land-stations may be found in the place where the observations were made. This was situated on the western outskirts of the

[2]Électricité atmosphérique (1924), le troisième fascicule, p. 89.
[3]Electrical conductivity of the atmosphere (1927), p. 44.

city. During the majority of the observations the wind had a westerly component. Hence the smoke from the city did not approach the station and so the ions were not eliminated by the formation of "large," or Langevin ions. Also towards the west and northwest the country is largely agricultural. As a result the air under investigation was about as free of dirt particles as that of the open country. Hence the values might be expected with fair reason to approach the normal.

Variations throughout the day—Table 1 shows that a distinct maximum occurs in the early afternoon, forenoon and evening showing smaller values.

Whether these smaller numbers are minima, thus indicating a double daily period or not, cannot be determined without a more complete series of observations. The hours, however, agree with those where a double daily period has been found, both as regards the time of the afternoon maximum and the times when minima are observed. Both positive and negative ions vary in number to about the same extent, the maxima being about 4/3 of the values found either in the morning or in the evening. The latter fall fairly close together.

Besides this diurnal variation of the averge values, other variations were noted. These appeared to depend very closely on meteorological conditions. With good visibility the ionic content was found to be high. Large numbers of ions were also found on days of gusty or squally winds, while on the other hand when visibility was poor or only fair through the presence of haze or mist, the numbers were below the mean. This deficiency can be attributed in all probability to the formation of large ions whereby numbers of the small ions were eliminated. It was not found possible to establish a relation between temperature and ionic content. The period of observation was however short, and the temperature-variation was also not very large. Further the variations arising from other causes were such as were likely to mask any variation due to alteration in temperature, a variation which under the present circumstances could only be slight. Indirectly, of course, the ionic content was found to be affected by change of temperature. With increase of temperature during the day there almost invariably occurred an increase of wind-velocity, and likewise an increase in the temperature of the topmost layers of the soil. Both these factors tend to increase the number of ions entering the air from the ground. In this we find one cause for the higher ion-concentration during the afternoon.

Summary

(1) The ionic content at Aberdeen is shown to approximate fairly closely to the average value for land-stations.

(2) The ionic content shows a distinct maximum in the early afternoon.

(3) The ionic content is influenced to a very great extent by the meteorological conditions prevailing at the time.

University,
Aberdeen.

DISTRIBUTION-COEFFICIENTS FOR VERTICAL-INTENSITY MAGNETIC VARIOMETERS[1]

By H. E. McComb

Abstract—Scale-values were determined in the usual manner by means of a small deflector at short distances and with the deflection-bar set for various azimuths. These were referred to the values obtained with a large deflector at a great distance as standard, and from the resulting differences the distribution-factors were computed.

In connection with a study of different types of pivots for vertical-intensity magnetic variometers, an extensive series of scale-values was made at the Cheltenham Magnetic Observatory. These observations consisted of the usual deflections of the recording magnets of the vertical-intensity and declination variometers at deflection-distances of 25 and 28 centimeters. Instead of confining the azimuth of the deflection-bar to one or two planes, observations covered a wide range of azimuths of the bar from 0° to 360° by steps of 10°. For purposes of comparison, observations were made also by means of a large deflector[2], at a deflection-distance of 192 centimeters and at 0° azimuth as described by A. K. Ludy in this number of the Journal. The scale-values were computed from the equation[3]

$$\epsilon=(2u/2u')\ (H/2R)\ (f/(f\text{-}h))\ (1+P/r^2) \qquad (1)$$

in which ϵ is the scale-value in gammas per millimeter, $2u$ is the double deflection of the D curve, $2u'$ the double deflection of the Z-curve, H the horizontal intensity in gammas, R the distance from the D-lens to the magnetogram, and h the angle through which the D-magnet is turned when the torsion-head is turned through an angle f. In the preliminary computations the term $(1+P/r^2)$ was omitted in all cases. The correction for any rational distribution-factor for the D-deflections with the large deflector at the distance used is negligible and the large deflector was of such a length that $P=0$ for the vertical-intensity variometer recording-magnet. The values of log $(1+P/r^2)$ were obtained by taking the differences between log ϵ (small deflector) and log ϵ (large deflector) for all azimuths. In these computations the values $2u\ (H/2R)$ $(f/(f\text{-}h))$ were treated as constants, k_1 for $r=25$ cm and k_2 for $r=28$ cm (log $k_1=2.1253$ and log $k_2=1.9780$). The scale-value as computed from the deflections with the large deflector at 192 cm was 4.629.

Table 1 shows the values of $2u'$ for the different azimuths with small deflector at deflection-distances of 25 and 28 cm and

[1]Published by permission of the Director of the United States Coast and Geodetic Survey.

[2]H. E. McComb, *Terr. Mag.*, v. 33, 1928 (65).

[3]D. L. Hazard, Directions for magnetic measurements, p. 106.

the values of P as computed for the mean values of $2u'$ for each group of four positions of the bar making equal angles with the magnetic meridian. The last column gives the values of P as computed from equation (2). In an unpublished paper George Hartnell, Observer-in-Charge of the Cheltenham Magnetic Observatory, derives the following relation

$$P = 6l_s^2\,(1 - 5/4\,\sin^2\beta) - (3/2)\,l_a^2 \qquad (2)$$

in which P is the first distribution-coefficient in the scale-value equation, l_a is one-half the deflector pole-distance, l_s is one-half the recording magnet pole-distance and β the azimuth of the vertical plane through the magnet centers or through the horizontal axis

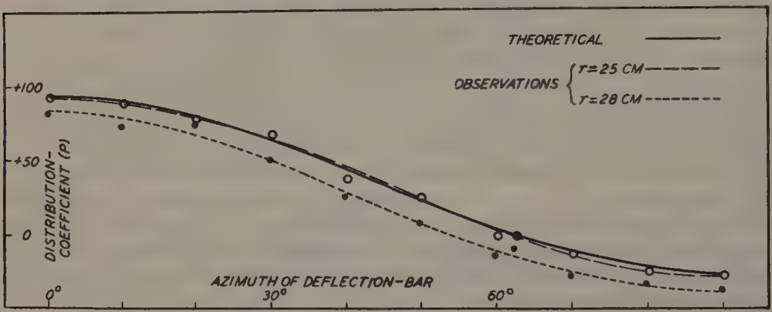

FIG. 1—Values of distribution-coefficients as computed from equation (2) and from observational data at distances 25 and 28 centimeters for various azimuths of the deflection-bar

of the deflection-bar, counting from magnetic south. The values of P as computed from equation (2) and from the observational data are plotted in Figure 1. A reproduction of the original magnetogram showing the deflections at the short and long distances is shown in Figure 2.

The pole-distances of the different magnets involved in this investigation are approximately as follows: Z recording-magnet $= 8$ cm; small deflector pole-distance $= 2$ cm; and large deflector

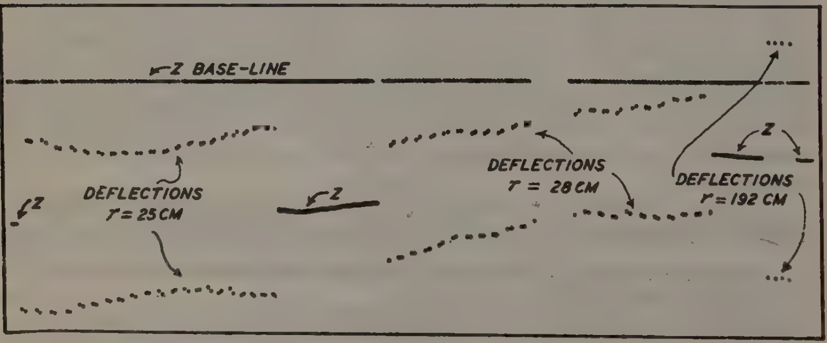

FIG. 2—Record reduced to two-thirds actual size of double deflections for vertical intensity at distances 25, 28, and 192 centimeters for different azimuths of deflection-bar from 0° to 360° by steps of 10°

pole-distance = 16 cm. As the true pole-distance is an uncertain quantity itself, the disagreement between the theoretical values of P and those obtained from observations may be traced in part to this fact. It might be stated in passing that the magnetic moment of the Z recording-magnet was 315 and that of the small deflector was 10.2.

TABLE 1—*Distribution-coefficients for Schulze variometer No. 20 as obtained at Cheltenham Magnetic Observatory, May 18, 1928*

Azimuth of deflection-bar	Deflection-distance, r, in centimeters				P from equation (2)
	25		28		
	Double deflection, $2u'$	Distribution-coefficient P	Double deflection $2u'$	Distribution-coefficient P	
° °	*mm*				
0–180	33.30		22.70		
180– 0	32.80		22.70		
Means	33.05	91.9	22.70	82.3	94.5
10–190	32.90		22.45		
170–350	32.90		22.50		
Means	32.90	88.1	22.48	74.5	90.8
20–200	32.40		22.20		
160–340	32.40		22.75		
Means	32.40	77.5	22.48	74.5	80.4
30–210	32.05		21.75		
150–330	31.75		21.95		
Means	31.90	66.9	21.85	50.2	64.4
40–220	30.40		21.10		
140–320	30.60		21.35		
Means	30.50	36.2	21.22	25.9	44.9
50–230	29.80		20.60		
130–310	30.10		20.90		
Means	29.95	24.4	20.75	7.8	24.1
60–240	28.85		20.20		
120–300	28.70		20.10		
Means	28.78	− 1.2	20.15	−14.9	4.5
62.5–242.5	28.70		20.15		
117.5–297.5	28.85		20.35		
Means	28.78	− 1.2	20.25	− 9.8	0
70–250	28.05		19.55		
110–290	28.40		20.10		
Means	28.22	−13.1	19.82	−28.2	−9.9
80–260	27.60		19.75		
100–280	27.80		19.65		
Means	27.70	−25.6	19.70	−32.9	−22.0
90–270	27.60	−27.5	19.60	−37.6	−25.5

The results show how difficult it is to reconcile observations at short deflection-distances even though the series is unbroken and was made in a comparatively short time. On the other hand when one considers all of the mechanical difficulties involved not only in the unavoidable instrumental imperfections but in the adjustment and manipulation of the short deflector on a deflection-bar attached to the variometer itself, there seems to be a fair agreement between observational results and equation (2).

U. S. COAST AND GEODETIC SURVEY,
WASHINGTON, D. C.
January 10, 1929

REVIEWS AND ABSTRACTS

(See also pages 22 and 83)

ANGENHEISTER, G. *Geophysik*. I. Teil, unter der Redaktion von G. Angenheister bearbeitet von G. Angenheister, J. Bartels, H. Benndorf, K. Büttner, A. Defant, W. Milch, L. Vegard. Wien-Harms, Handbuch der Experimentalphysik, Band 25, I. Teil. Leipzig. Akademische Verlagsgesellschaft m. b. H., 1928 (xiv+699 mit 185 Abbildungen).

That the time is past when one man could "take all knowledge to be his province" is amply verified by the series of general scientific handbooks by several collaborators, now in process of publication, and it is only too obvious, in view of the recent rapid advances in our knowledge of the physical sciences, that no one person could be expected to write adequately an exhaustive treatise on so vast a subject as experimental physics. Accordingly, the authorship of the work under consideration, which is the first part of the 25th volume of Wien and Harms, Handbuch der Experimentalphysik, and which bears the general title of "Geophysik," has been shared by six prominent specialists working under the general editorship of G. Angenheister.

The work is divided into seven main sections of which all but the last, deal primarily with atmospheric phenomena. In the opening section, A. Defant gives a general discussion of the physics of the atmosphere, considered under the two headings of statics and dynamics. The two following sections on tidal vibrations of the atmosphere and atmospheric optics are by J. Bartels and W. Milch, respectively. The fourth section contains a general discussion of atmospheric electricity by H. Benndorf in which the present status of our knowledge of the subject is very ably set forth from the viewpoint of the physicist. Principal weight is given to the exposition of methods of measurement and discussion of results, theoretical considerations receiving less attention. Next follows a treatment of northern lights by L. Vegard; he describes the auroral phenomena with reference to form and altitude, relationship with terrestrial magnetism and sunspots, the various theories regarding polar lights and the physical investigations connected therewith, the spectrum of the aurora, and the condition of the upper layers of the atmosphere, and concludes with an account of an experimental test of his own hypothesis. K. Büttner contributes a section on the penetrating-radiation. G. Angenheister and J. Bartels conclude the volume with an essay on the Earth's magnetic field, treating the subject under the following headings: Instruments and methods of measurement; the permanent field and secular variation; periodical variations and magnetic activity; magnetic disturbances.

The volume is provided with a convenient subject and author-index, and is characterized by the same excellency of printing and style of binding as the other volumes of the series.

H. D. HARRADON

VARIOMETER SCALE-VALUE DETERMINATIONS WITH A LARGE DEFLECTOR[1]

By A. K. Ludy

Abstract—Vertical and horizontal-intensity variometer scale-values were determined by the usual method of using a small deflector at short distances and a large deflector at great distances. The results indicate that the latter method has several advantages and is to be preferred.

It has been customary to determine horizontal-intensity, H, and vertical-intensity, Z, scale-values at the magnetic observatories of the United States Coast and Geodetic Survey by recording the deflections of the variometer-magnets produced by a small deflecting-magnet placed on a deflection-bar a short distance (25 to 30 cm) from the center of each variometer. The method consists in comparing the amounts by which the deflecting magnet deflects the magnets of the D- and H-variometers in the case of the H scale-value, and of the D- and Z-magnets in the case of the Z scale-value. In each case the deflecting magnet is similarly placed with respect to the variometer-magnets in question and at the same distance from each. The deflecting magnet is ordinarily of about the same size and shape as the suspended magnets in the D- and H-variometers. The relation, in the case of the H-variometer is shown by the formula[2]

$$\epsilon_h = (2u/2u')\ (H/2R)\ (f/(f-h))$$

where ϵ_h is the H scale-value, $2u$ is the number of mm which the D-spot is deflected, $2u'$ is the number of mm which the H-spot is deflected, R the distance from the D-lens to the magnetogram, and h is the angle through which the D-magnet is turned when the torsion-head is turned through an angle f.

Because of the difference in size and shape of the Z-variometer magnet, it is necessary to introduce a distribution-factor of the form $(1+P/r^2)$ into the above formula to make it apply to the Z-variometer. It was suggested by McComb[3] that if use was made of a deflector of large magnetic moment placed at a great distance from the variometers, the distribution-factor would be negligible, since the magnetic field produced by a bar-magnet becomes more and more uniform as the distance from the magnet increases. Incidentally, many other decided advantages are obtainable by the use of a large deflector for determining scale-values. Scale-value determinations may be made without entering the variometer-room, thereby avoiding abnormal temperature-changes during the operation. In the ordinary method of scale-value observations the deflector is placed on a deflection-bar attached to the variometer, and it is almost impossible to place the deflector in its various positions without jarring the variometer somewhat, which may result in change of base-line. This is particularly true in the case of the

[1]Published by permission of the Director of the United States Coast and Geodetic Survey.

[2]D. L. Hazard, Directions for Magnetic Measurements, second edition, pp. 100-106.

[3]H. E. McComb, *Terr. Mag.*, v. 33, 1928 (65).

Z-variometer. In the large deflector method this difficulty is eliminated. Because of the greater deflection-distance used the relative error in determining the deflection-distances is decreased. The new method as outlined below requires less time than the old method. Another advantage is that the variometers may be inclosed in a box of "Celotex" or other material which would serve as a further protection of the instruments against moisture, troublesome insects, and changes in temperature.

A trial of the method was made at the Tucson Magnetic Observatory of the United States Coast and Geodetic Survey. A cobalt steel magnet 1 by 1 by 20 cm in size, having a magnetic moment of about 14,000, was used for a deflector. The deflection-distance used was 316 cm. The Z-variometer used in the tests had been in operation continuously for five months and had apparently reached a stable condition some time before the tests were made. The D- and H-variometers had been in continuous operation for a number of years.

The magnetic observatory at Tucson is well suited for this method of scale-value determinations as it has a two-foot corridor between two sawdust-filled compartments which surround the variation-room. A shelf for holding the deflecting magnet was erected in this corridor on the south side of the variation-room. To determine the deflection-distance two holes were bored through the inner sawdust-filled space into which were fitted two-inch cardboard mailing tubes. Through these tubes equal distances from the center line of the variometers were laid off and a line parallel to this center line was scribed on the shelf. Also lines were scribed on the wall of the corridor at the height of the three variometer-magnets and in the magnetic meridian. These lines fixed the positions for the deflecting magnet in the scale-value determinations.

The deflecting magnet was inclosed in a case of wood, having about an inch of wood all around the magnet. This case insulated the magnet against the heat of the observer's hands while placing it in the various positions. On five different days in November 1928, complete tests were made which consisted of scale-value determinations for H and Z with the large deflector, followed by determinations with the small deflector, followed by a second determination with the large deflector. The results of these tests are shown in Table 1. Deflections with the large deflector were made in the following order: Z, north end up and down, face north; D, north end east and west, face north; H, north end north and south and north, face up; D, north end west and east, face north; Z, north end down and up, face north.

In computing the Z scale-values, distribution-factors were used in the case of the small deflector but none in the case of the large deflector. It can be shown that the field-strenth of the magnet deflecting the D-variometer is twice as great in the first position of Gauss (deflections for H scale-value) as it is in the second position of Gauss (deflections for Z scale-value). Therefore, but one set of D-deflections was made with the large deflector, that for Z scale-

value, and this value of $2u$ was doubled for use in the H scale-value computations.

In order to avoid confusion of the registered deflections, a screen was provided for each variometer. The screens were connected to the corridor by means of string so that they could be manipulated from the corridor and the appropriate shutters made to cut off the light from the variometers not under test.

The Z scale-values are given in Table 1, using (*a*) The distribution-coefficients furnished from observational data obtained at Cheltenham Magnetic Observatory when the instrument was standardized; (*b*) using distribution-coefficients obtained from a least-square adjustment of scale-values covering several months observations with the small deflector after the instrument was placed in operation at the Tucson Observatory; and (*c*) using distribution-

TABLE 1—*Scale-values with Schulze vertical-intensity variometer No. 20 at Tucson, Arizona, using distribution-coefficients obtained by different methods*

Deflec-tion-dist.	Posi-tion bar	Dis.-coeff. P	log $(1+P/r^2)$	Date November 1928					Means
				20	21	22	23	28	
cm									
25.77	NS	+125	0.0749	3.18	3.24	3.24	3.31	3.37	3.27
28.77	NS	+125	0.0611	3.14	3.14	3.24	3.26	3.26	3.20
25.77	EW	− 15	9.9901	3.08	3.13	3.18	3.12	2.98	3.10
28.77	EW	− 15	9.9921	3.11	3.15	3.20	3.16	3.08	3.14
25.77	NS	+ 82.0	0.0506	3.00	3.06	3.06	3.13	2.99	3.05
28.77	NS	+ 82.0	0.0410	3.00	3.10	3.11	3.11	3.11	3.09
25.77	EW	− 23.1	9.9846	3.02	3.07	3.12	3.06	2.92	3.04
28.77	EW	− 23.1	9.9877	3.08	3.12	3.17	3.13	3.05	3.11
25.77	NS	+129.2	0.0772	3.20	3.26	3.26	3.33	3.38	3.29
28.77	NS	+140.0	0.0679	3.19	3.29	3.31	3.31	3.31	3.28
25.77	EW	+ 24.1	0.0155	3.26	3.32	3.37	3.31	3.15	3.28
28.77	EW	+ 22.8	0.0118	3.25	3.30	3.35	3.30	3.22	3.28
316.	S	0	0.0000	3.39	3.31	3.32	3.32	3.35	3.34
316.	S	0	0.0000	3.11	3.22	3.25	3.22	3.36	3.23

TABLE 2—*Scale-values with Schulze vertical-intensity variometer No. 20 at Cheltenham, Maryland, June 1, 1928, using dip-circle bar-magnet No. 1 as a deflector*

Magnetic azimuth bar	Scale-values in gammas from deflection-distances in cm						Means
	188.9	183.9	178.9	173.9	168.9	163.9	
°							
0	3.98	4.01	3.96	4.02	3.99	4.02	4.00
N60W	3.98	3.99	3.93	4.01	3.97	4.01	3.98
	Mean						3.99

Table 3—*Horizontal-intensity scale-values with Schulze variometer No. 29 at Tucson, Arizona*

Date	Scale-values in gammas from position of deflection-bar and deflection-distance in cm							
	At ordinate *h*				At zero-ordinate			
	NS 25.77	NS 28.77	S 316.	S 316.	NS 25.77	NS 28.77	S 316.	S 316.
1928								
Nov. 20	2.38	2.38	2.40	2.42	2.06	2.07	2.09	2.10
21	2.39	2.40	2.43	2.43	2.07	2.07	2.10	2.09
22	2.41	2.42	2.44	2.45	2.07	2.07	2.09	2.10
23	2.38	2.39	2.42	2.42	2.06	2.06	2.10	2.10
28	2.38	2.38	2.38	2.42	2.08	2.08	2.08	2.12
	Means				2.07	2.07	2.09	2.10

coefficients which will reconcile all observations at all distances and different azimuths, for the series from November 20 to 28, 1928. The length of the large deflector was made equal to 20 centimeters so that in the north-south position the distribution-coefficient, P, would be zero for the vertical-intensity variometer, its recording magnet being 10 centimeters long. The effect is so small for the D-deflections that it may be neglected. In the horizontal-intensity scale-values the distribution-effects balance as the recording magnets are of about the same dimensions.

Table 2 shows some preliminary results obtained by H. E. McComb at the time of standardization of Z-variometer No. 20 at Cheltenham, Maryland. The instrument was operating at a sensitivity differing somewhat from that used at Tucson. The results for different deflection-distances and azimuths are very consistent and have been computed without applying any correction for distribution.

Table 3 gives the computed H scale-values for the different distances for the ordinates at which deflections were made and the values as reduced to zero-ordinate. For this H-variometer the relation between the scale-value, ϵ_0 at zero ordinate and, ϵ_h, at ordinate h is given by $\epsilon_h=\epsilon_0+0.005\ h$. There is a close agreement in the means for the different distances. In case of H scale-values there has been little difficulty in securing satisfactory accuracy by the old method, and this is confirmed by the results in Table 3. In the case of Z scale-values, however, there always has been an uncertainty as to what factors should be used for distribution, an uncertainty which has been eliminated by the new method. The better agreement of results by the new method is a further indication that the use of the large deflector is to be preferred.[4]

[4]A preliminary test of the new method at the Sitka Magnetic Observatory by F. P. Ulrich gives a result for Z scale-value considerably higher than that obtained by the old method and again shows the uncertainty in the derivation of a distribution-factor from observations at short deflection-distances. Further extensive tests by G. Hartnell and S. Townsend at the Cheltenham Magnetic Observatory have also shown the superiority of the new method.

Tucson Magnetic Observatory,
Tucson, Arizona,
January 10, 1929

METHOD IN OSCILLATIONS[1]

By W. N. McFarland

Abstract—The aim of this paper is to develop the best arrangement of the oscillation-observations of the measurement of horizontal intensity, by consideration of the relative precisions obtained by varying the length of the series and the method of computation. The variation of precision in the final mean value with arrangement of the observational and computational work is shown by a figure, and the formula is stated for the propagation of this observational error into the computed value of the horizontal intensity.

The measurement of the magnetic horizontal intensity involves as one of its two fundamental parts, the determination as accurately as may be, of the time consumed by a magnet in completing one oscillation. Obviously the precision of the measured periods depends upon several factors, such as the length of the series and the skill of the observer. It is possible also to bring to the aid of the observer in arranging his observations some conclusions derived from analysis which enable him to get the maximum of precision from the work done. This consideration of errors is applicable to any method of determining the length of the periods, whether it be mechanical as in the photo-electric method which has been developed recently jointly by the Department of Terrestrial Magnetism and the Coast and Geodetic Survey, or the eye-and-ear method usual for work in field and observatory.

By either method the procedure is to set the magnet swinging, and then to time its transit, across a slit in the photo-electric method, or across a vertical wire in the diaphragm of a telescope in the eye-and-ear method. It is customary to continue these observations of the time of transit at intervals of a chosen number of oscillations until a series has been obtained. Such a series by the eye-and-ear method is given in Table 1 as an illustration of the process, together with the computation by means of which the length of the period of one oscillation is obtained. The oscillations between 45 and 100 were not timed. The question naturally arises, how these observations can be arranged to secure both a maximum of precision in the resulting period of one oscillation, and at the same time a minimum of observation. The following consideration of such a series is devised to throw light on these aspects of the problem.

[1]Published by permission of the Director of the United States Coast and Geodetic Survey.

TABLE 1—*Sample observation and computation of the period of one oscillation*

Observation				Computation		
No.		Oscillations	Time	No.	Period	Time
			h m s.			m s
1	a_1	0	13 00 20.1	T_1	100 − 0	5 17.4
2	a_2	5	35.9	T_2	105 − 5	17.4
3	a_3	10	51.8	T_3	110 − 10	17.3
4	....	15	01 07.7	....	115 − 15	17.3
5	....	20	23.6	....	120 − 20	17.4
6	....	25	39.5	....	125 − 25	17.3
7	....	30	55.3	....	130 − 30	17.3
8	....	35	02 11.2	....	135 − 35	17.3
9	a_{n-k}	40	27.1	T_{n-k}	140 − 40	17.4
10	a_{n-k+1}	45	42.9	T_{n-k+1}	145 − 45	17.4
21	a_k	100	13 05 37.5		Mean.......	5 17.35
22	a_{k+1}	105	53.3			
23	....	110	06 09.1	T_0....................		3.1735
24	....	115	25.0			
25	....	120	41.0			
26	....	125	56.8	$n=30$; $k=21$; $d=5$		
27	....	130	07 12.6			
28	....	135	28.5			
29	a_{n-1}	140	44.5			
30	a_n	145	08 00.3			

In any such series, let n be defined as the total number of observations of a series in which there are no omissions, a as the chronometer time of any single observation, running from a_1 to a_n, and d as the number of oscillations between observations. Also let k' and k be numbers in the series at which subtractions, as in the illustration, are started, the distinction being made that k' shall be a number in the first half of the series, and k a number in the second half of the series.

Considering first the effect of starting subtractions before the midpoint of the series, we can combine the observations in the following manner, using primes to designate T and k in this half of the series

$$
\begin{aligned}
T'_1 &= a_{k'} - a_1 \\
T'_2 &= a_{k'+1} - a_2 \\
\cdots\cdot &\quad \cdots\cdots\cdots\cdots \\
\cdots\cdot &\quad \cdots\cdots\cdots\cdots \\
T'_{n-k'} &= a_{n-1} - a_{n-k'} \\
T'_{n-k'+1} &= a_n - a_{n-k'+1}
\end{aligned}
$$

The number of oscillations in any period T' is $d(k'-1)$ and the number of periods is $(n-k'+1)$, so that the mean value of a single oscillation is

$$T'_0 = (T'_1 + T'_2 + \ldots\ldots + T'_{n-k'} + T'_{n-k'+1})/d(k'-1)\ (n-k'+1)$$

If we examine again the series of subtractions, it can be noted that all the observations from $a_{k'}$ to $a_{n-k'+1}$ inclusive occur twice in the series and with opposite signs, so that they cancel out and have no effect on the resulting mean. So when T' is replaced by its equivalents, the mean period

$$T'_0 = [(a_{n-k'+2}+a_{n-k'+3}+\ldots\ldots+a_n)-(a_1+a_2+\ldots\ldots+a_{k'-1})]/d(k'-1)(n-k'+1)$$

Turning now to the case where the subtractions are started beyond the midpoint of the series, we have as before

$$\begin{aligned} T_1 &= a_k - a_1 \\ T_2 &= a_{k+1} - a_2 \\ \ldots &\ \ldots\ldots\ldots \\ \ldots &\ \ldots\ldots\ldots \\ T_{n-k} &= a_{n-1} - a_{n-k} \\ T_{n-k+1} &= a_n - a_{n-k+1} \end{aligned}$$

In this case there are a number of observations, from a_{n-k+2} to a_{k-1} inclusive, which do not appear in this formula, and in consequence have no effect on the mean. As before there are $d(k-1)$ oscillations in each T and $(n-k+1)$ periods, so that the mean value of a single oscillation becomes

$$T_0 = [(a_k+a_{k+1}+\ldots\ldots+a_n)-(a_1+a_2+\ldots\ldots+a_{n-k+1})]/d(k-1)(n-k+1)$$

An examination of this formula shows that there are $(n-k+1)$ terms in both halves of the numerator. In T'_0 there are $(k'-1)$ terms in both halves. Putting $n-k+1=k'-1$; $k+k'=n+2$; $k'=n-k+2$; $k'-1=n-k+1$; $n-k'+1=k-1$; and

$$T'_0 = [(a_k+a_{k+1}+\ldots\ldots+a_n)-(a_1+a_2+\ldots\ldots+a_{n-k+1})]/d(k-1)(n-k+1)$$

Consequently if $(k+k')=(n+2)$, $T'_0=T_0$, and any combination of observations in which k is less than $(n+2)/2$ will be identical with another combination in which k is greater than $(n+2)/2$ by the same amount, and the series of combinations will be symmetrical with respect to this point. The examination of one half of the possible number of combinations can then be omitted. As the number of subtractions is less when k is large, the second half of the series should be used in practice, so that resulting means will be derived from

$$T_0 = [(a_k+a_{k+1}+\ldots\ldots+a_n)-(a_1+a_2+\ldots\ldots+a_{n-k+1})]/d(k-1)(n-k+1)$$

It must be allowed that the observer makes a certain amount of error in his estimation of the time of transit. Each period in these computations will be the difference between two observed times and, as we are concerned with periods, the unit of error in observation may be taken as the probable error of any period, the

difference of two observed times. There are $(n-k+1)$ terms in each half of the numerator of T_0, so that if r be the probable error of any single period, the probable error of the numerator is $r(n-k+1)^{1/2}$. Also, if r_0 be the probable error of T_0, then

$$r_0=r(n-k+1)^{1/2}/d(k-1)\ (n-k+1)$$

$$r_0=r/d(k-1)\ (n-k+1)^{1/2}$$

which expresses the law of propagation of observational error into the mean value.

In a series of observations of a given length, it is possible to determine what value of k will give the most precise method of computation. The greatest precision will occur when r_0 is a minimum, or when $d(k-1)\ (n-k+1)^{1/2}$ is a maximum. If we take the denominator of the right-hand side of this equation as a measure of precision, it will satisfy the requirement that such a measure shall be inversely proportional to the error. Directly, it is the ratio of the error of observation in a single period, to the error of the mean value of a single oscillation. Putting then

$$\phi=d(k-1)\ \ (n-k+1)^{1/2}$$

and differentiating with respect to k

$$\mathrm{d}\phi/\mathrm{d}k=d(2n-3k+3)/2(n-k+1)^{1/2}$$

For a maximum value of ϕ

$$2n-3k+3=0$$

and

$$k=(2n/3)+1$$

Let us apply these formulas to the arrangement of observations used as an illustration. In this arrangement $(2n/3)+1=21$, which is the best value of k. As it happened this was also the value used by the observer. Then the precision gotten from this value of k is $\phi_{21}=5(20)\ (10)^{1/2}=316$.

From Figure 1 it can be seen that the combination which gives the least precision is that in which the first and last observations alone of the series are used. For this method of combination k is 30 and $\phi_{30}=5\ (29)=145$. Comparing ϕ_{30} with ϕ_{21} we see that the precision of ϕ_{21} could have been obtained by extending $d(n-1)$ from 145 to 316 and timing only the first and last transits.

The salient point of the whole discussion is that the precision as far as that is affected by method, depends mainly upon the length of the series, and only secondarily upon the number of intervening observations. This conclusion is rather obvious from the principles which govern the precision of mean values. If the periods of $d(k-1)$ oscillations resulting from the subtractions are called sets, the number of sets is $(n-k+1)$, and the precision of the mean value of the sets increases only as the square root of their number, whereas

the precision increases directly as $d(k-1)$, which is the number of oscillations in a set.

A practical point about these observations is that they are observations of half-oscillations, the time of transit being taken first with the magnet moving to the right and then to the left. On account of the fact that the vertical wire of the telescope may not be exactly at the center of the swing, only periods of complete oscillations should be used, so that it is not permissible to subtract an even number of half oscillations from an odd number, or vice-versa. This limits d and k in practice to odd numbers, as the product $d(k-1)$ should be even. The maximum value of k in practice is then $(n-1)$ and the total number of observations (n) should be an even number.

Figure 1 has been constructed to show what range of precision may be expected from varying the value of k. The equation of the curve is $\phi = d(k-1))\ (n-k+1)^{1/2}$ using the value 30 for n which is the value in the series used for illustration. As was brought out in

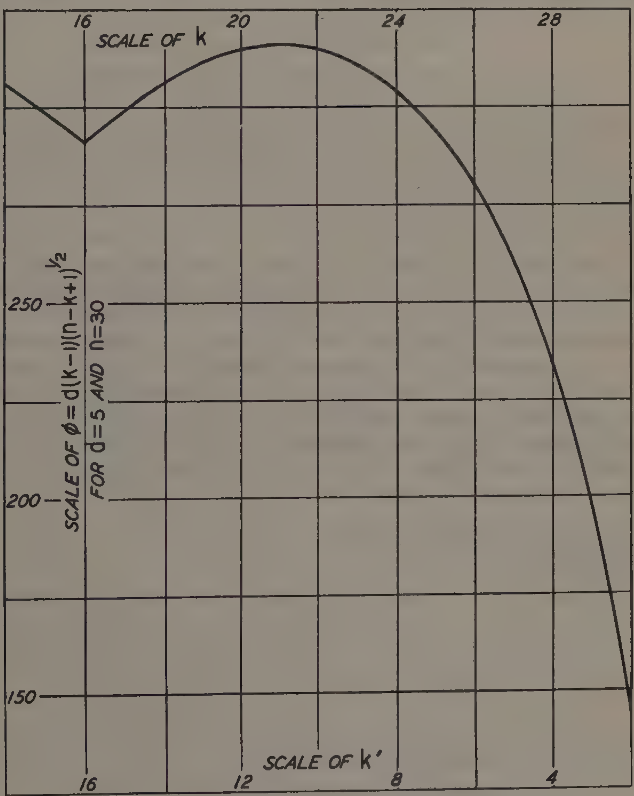

FIG. 1—Variation of precision with k

the beginning of this discussion, the same curve can be used for both halves of the series. The values of k are written at the top with the corresponding values of ϕ as ordinates, and the values of k' at the bottom. It will be evident from the form of the curve that while it has a definite maximum, there is no great falling off in precision throughout a considerable range of k, so that in practice, to save observational and computational work, k can well be taken somewhat larger than the theoretical best value.

Now for a few words in regard to the propagation of errors in timing oscillations into the computed value of the horizontal intensity. According to the law of propagation of error as it is stated in least-squares, any error in T_0 appears in H according to the formula

$$r^2_H = (\mathrm{d}H/\mathrm{d}T_0)^2 r_0^2$$

where r_H is the corresponding error in the horizontal intensity. We get from the oscillations a value of (HM) and from the deflections a value of (H/M). Also

$$HM = \pi^2 K/T_0^2$$

$$H^2 = (H/M)\ (\pi^2 K/T_0^2)$$

Before differentiating H it should be noticed that (H/M) is a quantity not included in the variation of H with T_0, and in consequence should be treated as a constant. Then $\mathrm{d}H/\mathrm{d}T_0 = -H/T_0$ and $r_H = -(H/T_0)\ r_0$.

This discussion of errors as far as it relates to method takes into consideration only one source of error, that due to the so-called accidental errors of timing. It does not apply to any constant errors, such as might be present in the adopted value of rate for the time-piece used. This would be a systematic error determinable only by an examination of the performance of the chronometer. To sum up all the errors which enter into the computed value of the horizontal intensity would require the classification and analysis of those due to clock-rate, temperature-changes, angle-measurements, etc., not only in oscillations but also on the deflection side of the observations.

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ON CERTAIN SOURCES OF ERROR IN DETERMINATIONS OF MAGNETIC DECLINATION

By Gustaf S. Ljungdahl

Abstract—In a magnetometer, fitted with an optical collimating-system attached to the magnet, a possibility exists of corrections, which are due to defects in the lens. A perfect magnetometer ought not to have any corrections at all in determinating D. A criterion of non-correction is given. Errors of observation may be diminished by pointing on more than one reticle in the field of view of the telescope.

(*I*) *A source of error in declination-determinations with a C.I.W.-pattern-magnetometer*—In 1927 the Magnetic Section of the Royal Hydrographic Service (Kungl. Sjökarteverket), Stockholm, received a C.I.W.-pattern combined magnetometer[1] and earth inductor No. 108, maufactured by Precise Instrument Company of Brooklyn, New York. The constants were determined with great care by the Carnegie Institution of Washington, and in October 1927 compared with those of the magnetic observatory at Copenhagen (Rude Skov).

The test at Washington indicated a correction of $-0'.3$ for observed values of D. The magnet-house being of mahogany, this correction could not be explained by assuming magnetic material in the house. During the comparisons at Rude Skov, however, it further appeared that the correction was not constant. The numbered and lettered side of the magnet in the position east-west did not show the same correction as in up-down position. Various heights of the magnet indicated also different corrections.

A magnet of the C.I.W.-pattern magnetometer consists, as is well known, of a hollow cylinder fitted with a collimating optical system. The explanation of these various corrections may be found in an irregular refraction in the lens, possibly arising from some deforming tension in its brass-frame. In this case, a magnet with a perfect lens would not show any correction, or—if some still did exist due to magnetic material in the theodolite—this correction should be the same with the magnet when "east-west" as when "up-down," the height of the magnet of course being unaltered. The lens, however, could not be replaced without spoiling the constants for determination of horizontal intensity. But determinations of declination with another magnet, manufactured by Laessöe-Müller of Copenhagen, in the same magnetometer did not show any corrections when compared with the instruments of Rude Skov. A few weeks after my comparisons were made, Professor Venske, who compared the instruments of this Observatory at Rude Skov with those of Potsdam[2], found no difference in declination between Potsdam and Rude Skov.

From the foregoing it may be considered as proved that the correction of the C.I.W.-pattern magnetometer No. 108 was due to the lens of the collimating system.

(*II*) *Criterion of non-correction*—The above-mentioned effect of irregular refraction of the lens on D-determinations resembles closely the effect of magnetic material in some parts of the mag-

[1] *Terr. Mag.*, v. 16, 1911 (1).

[2] O. Venske, Ein Vergleich der erdmagn. Normalinstrumente von Potsdam und Rude Skov, Ber. über die Tätigkeit des Preuss. Met. Institutes im Jahre 1927, Berlin, 1928 (111).

netometer, perhaps the most frequent source of error. In both cases systematic errors may arise as well as increased uncertainty. Even if wood or chemically pure bronze may be considered non-magnetic to a degree sufficient for terrestrial-magnetic instruments, it is nevertheless within the bounds of possibility that they may become magnetic, because of filings, varnish, or adhering iron particles.

Several tests can be made for defects. Thus the magnet may be raised or lowered, and the poles of the magnet brought nearer to, or farther away from, the sides of the magnet-house either by raising the torsion-head or by inclining the instrument with the foot-screws. If the image of the cross-wires moves when the magnet is so displaced the influence of magnetic material or of certain optical defects may be suspected.

A criterion of absence of correction may be found when determinations of declination with different magnets in the same instrument give identical results within the error of observation, and when determinations with the same magnet in different magnetometers likewise give the same results. In case of divergence, the cause may be examined and eliminated. A perfect magnetometer ought not to have any correction at all in terminations of the magnetic declination.[3] The foregoing reflections may seem to be self-evident, but nevertheless a number of magnetometers, perfect in all other respects, are affected with defects, causing quite needless corrections.

(*III*) *On eliminating certain errors of observation*—A determination of the magnetic declination consists essentially of measuring an angle between a distant reference-mark and the axis of the magnet.

This measurement of an angle is affected by several errors, namely: (1) Errors of sighting; (2) eccentricity, regular errors, and accidental errors of circle-graduation; (3) for reading vernier, errors of its graduation, errors of reading and errors of parallax, which can be increased when the elimination is from one side and when the vernier is protected by a refracting glass-cover, now and then damp; or for reading microscope, error of runs, defects of the screw, etc. Other existing errors, namely, such produced by defects on the center-spindle, by inclination of the instrument, etc., will not be discussed here.

The errors of sighting are eliminated through repeated pointings, and the eccentricity by taking the mean of two verniers or of two microscopes 180° apart. The other errors, (1), (2), and (3), can be fully eliminated only by reading the circle at a great number of equidistant points. But the repetition-method may not be generally used in determinations of the magnetic declination, and the majority of magnetometers may not be fitted with repeating circles.

Most of the errors mentioned, however, may easily be diminished by sighting on more than one reference-line on the reticle in the field of view of the telescope. The telescope reticle being fitted with a graduated scale, the image of the object sighted upon may be brought upon more than one division of the scale, and if it be

[3]*Cf.* D. LA COUR, Om et nyt Apparat til jordmagnetiske Maalinger, *Fysisk Tidskrift*, Kjø-havn, v. 25, 1927 (106).

fitted only with cross-wires, some additional vertical wires may be easily fixed on the diaphragm. Each separate wire may be first made to coincide with the image of the reference-mark, and then to coincide with its proper image, reflected by the mirror attached to the magnet. (Note that the images are inverted!) In this way separate measurements of the angle between the reference-mark and the magnet can be made. These measurements of the angle may not be identical because of errors of observation, but their mean may be bettered.

The error of pointing may be diminished by pointing on several scale-divisions of the reticle or fixed cross-wires. For reading verniers, the same divisions are not read, neither on the graduated circle nor on the verniers. In this way one eliminates accidental errors of the circle, errors of graduation of the verniers, errors of reading and of parallax, and errors caused by existing glass-covers. Besides, with a single reticle the observer may repeat the first reading at subsequent pointings. The influence of the regular errors of the circle-graduation remains mainly corrected. For reading good microscopes, the ameliorating effect of the method may be less prominent. Accidental errors, defects of the screws of the microscopes, etc., may be eliminated to some extent.

For determinations of declination with C.I.W.-pattern magnetometer No. 108, fitted with a graduated scale in the telescope, I have pointed at divisions 20, 25, 30, 35, 40, that is, at 5 different divisions, the distance between 20 and 40 being about 40.8 minutes of arc. The instrument is fitted with two verniers, the least count of each being one minute of arc; the graduation is such, that estimations to one-quarter minute of arc can be made. The verniers are protected by glass-covers. As an example of the accuracy of reading, attainable with this instrument, the values in Table 1 are given, *the reference-mark having been sighted upon before and after the magnet-readings*. The values are the means of readings of the two verniers at the repeat-station Vågholmen (Sweden).

Further, during September to October 1928, D was determined at the Lovö (Stockholm) magnetic recording station, with the same instrument, mounted on a pier. The differences between the mark-readings before and after the magnet-readings were 0′.11, 0′.09, 0′.10, 0′06, 0′.13, 0′.02, 0′.07, and 0′.04. The relative accuracy of the corresponding absolute observations of magnetic declination appears from Figure 1 representing the base-line values computed from these determinations.

The determinations were made with the Læssöe-Müller magnet, and each single magnet-reading is simultaneously recorded by a light-beam on the photographic paper, in the same manner as at the Godhavn (Greenland) Observatory.[4]

[4] J. Olsen, Direct determination of scale-values at the magnetic observatory at Godhavn. Inst. Météorol. Danois, Communications Magnetiques, No. 2, Köbenhavn, 1927 (1).

TABLE 1—*Summary of mark-readings with C.I.W.-pattern magnetometer-inductor No. 108 at Vågholmen*

Date	On scale	Before magnet-readings	After magnet-readings	Difference
1928	d	° ′	′	′
June 14	40	5 26.4	26.5	−0.1
	35	16.0	16.1	−0.1
	30	05.6	05.8	−0.2
	25	4 55.8	55.6	+0.2
	20	45.2	45.2	0.0
Means	30	5 05.80	05.84	−0.04
June 14	40	324 34.5	34.4	+0.1
	35	24.5	24.5	0.0
	30	14.0	13.8	+0.2
	25	03.6	03.8	−0.2
	20	323 53.6	53.8	−0.2
Means	30	324 14.04	14.06	−0.02
June 15	40	143 25.0	25.0	0.0
	35	14.6	14.7	−0.1
	30	04.4	03.8	+0.6
	25	142 54.4	54.2	+0.2
	20	44.0	43.9	+0.1
Means	30	143 04.48	04.32	+0.16
June 15	40	144 19.2	19.1	+0.1
	35	08.8	08.9	−0.1
	30	143 58.9	59.0	−0.1
	25	48.4	48.4	0.0
	20	38.2	38.0	+0.2
Means	30	143 58.70	58.68	+0.02

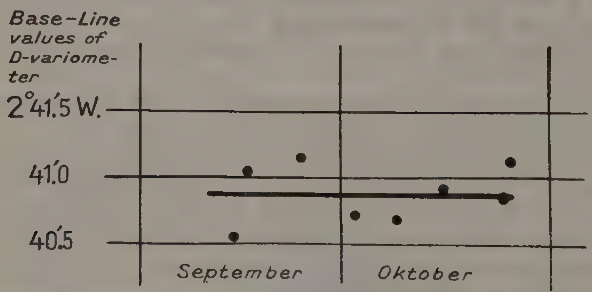

FIG. 1—Plot of base-line values determined at Lovö in September and October 1928. (Mean error of a single determination, including the errors of reading the photographic record, ±13″)

The comparisons of the Carnegie Institution, in 1927, with the same instrument and its own magnet showed a mean error of ±46^m for a single determination of declination; the mean error was computed from the differences between determinations with two magentometers.

KUNGL. SJÖKARTEVERKET,
STOCKHOLM, SWEDEN,
December 1928

SEBASTIAN JACOB MAUCHLY, 1878-1928[1]

By O. H. Gish

Dr. Sebastian Jacob Mauchly, Chief of the Section of Experimental Work in Terrestrial Electricity at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, died December 24, 1928 after a long and baffling illness. He was born at Swanton, Ohio, July 9, 1878, attended the University of Ohio, the University of Chicago, and the University of Cincinnati. From the latter institution he received the degree A.B. in 1921 and Ph.D. in 1913. His academic work was interspersed with the teaching of physics in high schools from which he carried a lasting interest in pedagogical problems. While Hanna research-fellow at the University of Cincinnati he developed, in collaboration with J. E. Ives, a new form of earth inductor. During the course of work for his doctor's thesis he was led to a disproof of the "magnetic rays" postulated by the eminent Italian physicist Righi. In this work he manifested the critical scrutiny which characterized all his later work and which established in those who knew him great confidence in his scientific conclusions. In 1914 while head of the department of physics in the Woodward High School of Cincinnati he was called to the Department of Terrestrial Magnetism as Associate Physicist and in 1919 he was made Chief of the Section of Terrestrial Electricity.

His earlier years in this Department were given largely to the development of instruments and methods for observing and recording atmospheric-electric conditions at the Watheroo and Huancayo magnetic observatories and on the *Carnegie* as also to scrutinizing of data with a view to attaining an ever higher standard of reliability. He developed the equipment and methods used in recording the potential gradient or electric intensity of the atmosphere on the Baffin Land as well as on the North Greenland expeditions of Macmillan (1921-22 and 1923-24) and effected improvements in the instrumental equipment used in the observations of potential gradient on the *Maud* Expedition (1922-25). He was also responsible for the instruments and methods used on four eclipse expeditions and personally took part in the observations at Lakin, Kansas, during the solar eclipse of June 8, 1918, and at Greenport,

[1]The portrait of Dr. Mauchly, from which the frontispiece was made, was kindly supplied by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

Long Island, during the eclipse of January 24, 1925. His careful technique and methods were imparted to many observers who received special training under him in the measurement of atmospheric-electric elements.

In the last few years of his active life Dr. Mauchly found time to take up more general investigations. The outstanding result of these later endeavors was the discovery that, at all places on the Earth's surface, an important part of the regular change, during the day, of the electric intensity in the atmosphere occurs in unison. He first found this to be true for the oceans where this type of change constitutes nearly the whole of the diurnal variation observed there. He later extended these investigations to include also all available observations over land where, although at times considerably entangled with other variables, he was nevertheless able to show that this type of variation also occurred. It was thus found that here is a phenomenon worldwide in extent and simultaneous in occurrence, the manifestation of a factor which affects the entire Earth at the same instant of time and which waxes and wanes in a regular manner throughout the day. With this remarkable discovery much that had been chaos became order. The regular daily changes over all oceans and in the polar regions were seen to follow a single universal schedule, while over land it was evident that other changes which follow a local schedule combined with this type. When viewed in this way explanations of the changes over land are considerably facilitated. Although this discovery made for clarity it also introduced a new problem or perhaps a new aspect of an old problem, since the mechanism by which this universal effect is produced may be the same as that which maintains the negative charge of the Earth. This discovery alone would permanently link his name with the science of atmospheric electricity.

Dr. Mauchly was a fellow of the American Physical Society, fellow of the American Association for the Advancement of Science, and member of the International Geodetic and Geophysical Union, of the American Geophysical Union, of the Washington Academy of Sciences, and of the Philosophical Society of Washington. He served on the Board of Editors of the Journal of the Washington Academy of Sciences, was co-author of Volume V, Researches of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, and author of numerous scientific papers a list of which, prepared by H. D. Harradon, is appended. In addition to the papers listed Dr. Mauchly contributed reviews of scientific papers to various publications from time to time.

A man of broad interests, a conscientious and active citizen, and a charming friend, he gave generously also of his time and energy to the civil and religious affairs of the community in which he lived.

List of Scientific Publications by Dr. S. J. Mauchly

A new form of earth inductor. (In collaboration with J. E. Ives.) Phil. Mag., v. 21, 1911 (579-583).

On the action of a magnetic field on the electric discharge through gases. (In collaboration with L. T. More.) Phil. Mag., v. 26, 1913 (252-267).

A study of pressure and temperature effects in earth-current measurements. Terr. Mag., v. 23, 1918 (73-91).

Results of magnetic and electric observations made during the solar eclipse of June 8, 1918. (In collaboration with L. A. Bauer and H. W. Fisk.) Terr. Mag., v. 23, 1918 (95-110, 155-190); v. 24, 1919 (1-28, 87-98).

Note on a possible explanation of the "electric tide" at Jersey. Terr. Mag., v. 24, 1919 (100-101).

Comments on Dechevrens' electric tide observations. Terr. Mag., v. 24, 1919 (179).

Results of atmospheric-electric observations made at Sobral, Brazil, during the total solar eclipse of May 29, 1919. (In collaboration with A. Thomson.) Terr. Mag., v. 25, 1920 (41-48).

Note on the diurnal variation of the atmospheric-electric potential-gradient. Phys. Rev., v. 18, 1921 (161-162).

Recent results on the diurnal variation of atmospheric electricity from observations aboard the *Carnegie*. Phys. Rev., v. 18, 1921 (161-162); J. Wash. Acad. Sci., v. 11, 1921 (398-399). [Summaries of papers read before the Section of Terrestrial Magnetism and Electricity, American Geophysical Union, Apr. 18, 1921; the Amer. Physical Society, Apr. 23, 1921; and the Philosophical Society of Washington, May 21, 1921.]

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A rotary slide-wire for producing uniform variation in potential difference. J. Optical Soc. Amer., v. 8, 1922 (852-858).

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The potential gradient at the Apia Observatory, Samoa, for the year ending April 30, 1923. Preliminary results. Abstracted in Carnegie Inst. Wash. Year Book 22, 1923 (263-264).

The diurnal variation of atmospheric-electric conductivity and air-earth current from observations obtained on the *Carnegie*. Abstracted in Carnegie Inst. Wash. Year Book 22, 1923 (264-265).

The results of potential-gradient registrations at Washington, District of Columbia, for the years 1917 to 1922. Abstracted in Carnegie Inst. Wash. Year Book 22, 1923 (265).

Report of the Committee on earth-currents and polar lights. Bull. Nation. Research Council, No. 41, 1924 (105-107).
Observatory equipment for recording photographically the conductivity of the air. Bull. Nation. Research Council, No. 41, 1924 (122-123).
On the diurnal variation of the potential gradient of atmospheric electricity. Bull. Nation. Research Council, No. 41, 1924 (131-135).
[The above three papers were presented before the Section of Terrestrial Magnetism and Electricity, American Geophysical Union, Apr. 18, 1923.]
An improved form of bifilar electrometer. (In collaboration with H. F. Johnston.) Abstract, Phys. Rev., v. 23, 1924 (302).
Improved apparatus for recording the electrical potential of the air. Phys. Rev., v. 23, 1924 (302-303). [Abstract of paper presented before the American Physical Society, Dec. 28, 1923.]
Atmospheric electricity. Q S T, v. 8, 1924 (37-40). [A popular exposition of the subject.]
The radium-emanation content of sea air from observations aboard the *Carnegie*, 1915-1921. Terr. Mag., v. 29, 1924 (187-194).
Report on magnetic and electric observations by the Carnegie Institution of Washington in connection with the total solar eclipse of January 24, 1925. (In collaboration with J. P. Ault and R. H. Goddard.) Terr. Mag., v. 30, 1925 (125-146).
The electrical condition of the lower atmosphere. Bull. Nation. Research Council, No. 53, 1925 (58-59). [Abstract of paper presented before the Section of Terrestrial Magnetism and Electricity, American Geophysical Union, Apr. 30, 1925.]
Note on the control of atmospheric potential-gradient observations at observatories. Trans. Madrid Meeting, Internat. Geod. Geophys. Union, Sec. Terr. Mag. Electr., Oct. 1924, Bull. No. 5, 1925 (150).
The electricity of the air. Sci. Mon., v. 21, 1925 (641-645). [Radio talk broadcast from station WCAP, Washington, D. C.]
On atmospheric electricity and the instruments of its measurement. Carnegie Inst. Wash. Year Book 24, 1925 (217). [Abstract of paper presented before meeting of American Meteorological Society, June 19, 1925.]
Ocean magnetic and electric observations 1915-1921. (In collaboration with J. P. Ault.) Washington, D. C., Carnegie Inst., Pub. 175, v. 5, 1926 (195-286).
Studies in atmospheric electricity based on observations made on the *Carnegie*, 1915-1921. Washington, D. C., Carnegie Inst., Pub. 175, v. 5, 1926 (385-424).
Control of ionium collectors used in potential-gradient registrations at the observatories of the Department of Terrestrial Magnetism. Abstracted in Carnegie Inst. Wash. Year Book 25, 1926 (227).
A modified Dolezalek quadrant electrometer for the photographic registration of the potential gradient of the air. Abstracted in Carnegie Inst. Wash. Year Book 25, 1926 (208).
On the method used for analyzing radioactive decay-curves obtained aboard the *Carnegie*. Abstracted in Carnegie Inst. Wash. Year Book 27, 1928 (260).

Department of Terrestrial Magnetism,
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Washington, D. C.

PROVISIONAL SUNSPOT-NUMBERS FOR NOVEMBER AND DECEMBER 1928

(Dependent alone on observations at Zürich Observatory)

Day	November	December	Day	November	December
1	53	...	16	*M*..[c]	89
2	47	55	17	49[a]	56[a]
3	49	64	18	52	..
4	..	*E* 95[c]	19	58	..
5	60[a]	128[b]	20	38	32
6	70	95	21	37	25
7	66	94[a]	22	28	..
8	53	85	23	..	23
9	*M*..[bc]	77	24	16	16
10	..	94	25	..	8
11	84[a]	*M*87[c]	26	29	13
12	..	..[a]	27	..	31
13	*M*101[bc]	..	28	..	37
14	73	..	29	8	*M*53[c]
15	77[a]	101	30	28	61
			31		71[b]

Mean for November (21 days): 51.2
Mean for December (24 days): 62.1

Mean provisional sunspot-number for the year 1928: 76.5

Zürich, Switzerland. W. Brunner

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory

October to December, 1928[1]

(*Latitude 57° 03′.0 N.; longitude, 135° 20′.1, or 9*^{h} *01*^{m}*.3 W. of Gr.*)

Greenwich Mean Time							Range		
Beginning			Ending				Decl'n	Hor. int.	Vert. int.
1928	*h*	*m*	*d*	*h*	*m*		′	γ	γ
October 18	7	28	19	02	..		150.0	1000	875*
October 24	6	35	25	11	..		84.0	756*	435
November 2	3	39	4	12	..		159.7	784	809*
November 13	3	..	14	01	..		52.7	417	400
December 5	16	17	6	21	..		55.7	523	663

[a]Passage of an average-sized group through the central meridian.

[b]Passage of a larger group through the central meridian.

[c]New formation of a larger or average-sized centre of spot activity: *E*, on the eatern part of the Sun's disc; *W* on the western part; *M* near the central meridian.

*Curve went off paper in one direction.

October 18-19, 1928—This storm has a very distinct abrupt beginning. The curves were smooth and normal up to $7^h 28^m$ where a sharp notch marks the beginning. At that time H decreases while D and Z increase a small amount. Almost immeduately after this beginning the curves go in opposite directions a much greater distance. The curves fluctuate till 8^h when H and Z decrease and D increases considerably. The curves go back and forth across the magnetogram making large ranges but slow enough to follow distinctly until about 12^h. The next six hours is a very mixed up bunch of spots. At 18^h the oscillations are still rapid but are decreasing in range until at 2^h on October 19 the curves are nearly normal again.

F. P. ULRICH, *Observer-in-Charge*

CHELTENHAM MAGNETIC OBSERVATORY

OCTOBER TO DECEMBER, 1928[1]

(*Latitude 38° 44′.0 N.; longitude 76° 50′.5 or 5^h 07^m.4 W. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Ver. int.
1928	*h m*	*d h m*	′	γ	γ
Oct. 18	7 25	19 01 ..	39.0	283	179
Oct. 24	17 50	25 05 ..	49.1	196	181

GEO. HARTNELL, *Observer-in-Charge*

HUANCAYO MAGNETIC OBSERVATORY

OCTOBER, 1928

(*Latitude 12° 02′.7 S.; longitude 75° 20′.4 or 5^h 01^m W. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Vert. int.
1928	*h m*	*d h m*	′	γ	γ
Oct. 18	7 24	19 04 ..	14.5	473	35
Oct. 24	17 50	26 24 ..	11.8	485	29

October 18, 1928—A violent magnetic storm began suddenly on October 18 at $7^h 24^m$ with an increase of 71γ in 3 minutes in horizontal intensity, and a marked increase in vertical intensity and decrease in declination. The horizontal intensity reached its maximum at $16^h 09^m$ and its minimum at $8^h 38^m$ on October 18, and during the whole period from the beginning of the storm to the end of the day showed large and rapid fluctuations with sharp peaks and deep bays. The most rapid change was a decrease of 153γ in four

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey

minutes, beginning at $8^h 34^m$. The vertical intensity and declination were also severely disturbed, giving a marked saw-tooth trace for both. After $23^h 12^m$ on October 18 the disturbance moderated greatly and ended at approximately 4^h on October 19, although there were several hours of subnormal horizontal intensity.

October 24, 1928—At $17^h 50^m$ on October 24 there was a sudden decrease of 18γ in horizontal intensity in one minute followed immediately by an increase of 114γ in four minutes, a total of five minutes. The vertical intensity and declination also showed small changes at this time. The storm which began thus was characterized by sharp, large, and rapid fluctuations in horizontal intensity and small but equally rapid variations in vertical intensity and declination during the daily maximum period of the 24th, 25th, and 26th and two deep bays in the horizontal-intensity trace during the first four hours of the 25th. The largest rapid change occurred on the 24th at $19^h 08^m$; a decrease in horizontal intensity of 312γ in five minutes. The first twelve hours of the 26th were practically normal, and after the end of the storm at approximately 24^h of the same day, all the elements gave practically normal traces.

All times given are Greenwich civil mean time.

PAUL G. LEDIG, *Observer-in-Charge*

REVIEWS AND ABSTRACTS

(See also pages 22 and 62)

BARANOW, W. J., und E. S. STSCHEPOTJEWA: *Ueber die Anwendung des Ebertschen Ionenzählers zur Bestimmung der Zahl und der Beweglichkeit der kleinen Ionen in der Atmosphäre.* Physik. Zs., Leipzig, 29 Jahrg., Nr. 21, 1928 (741-750).

The Ebert ion-counter is the most commonly used instrument, especially in the case of field-work for determining the number of small ions in the atmosphere. The presence of larger ions may however greatly affect the indications obtained with this instrument. Since this fact has been only recently realized, some of the older data thus obtained regarding the number of ions in the atmosphere and their computed mobilities, are being viewed with suspicion.

The Ebert counter, provided with a Wulf bifilar electrometer may be utilized for determining the correction necessary due to the presence of larger ions in the atmosphere although it is not well adapted for this purpose. Equipped with a Mache condenser, this instrument provides a more precise method, since it permits a direct determination of the correction. A still more accurate device for this purpose is the Ebert-Gerdien apparatus, which consists of two co-axial cylindrical condensers placed one behind the other along the air-flow tube, each having a separate electrometer. Results obtained by the authors employing the latter method, show corrections as large as 61 and 78 per cent respectively, owing to the number of positive and negative large ions in the atmosphere.

Laboratory experiments have shown that the mobility of the small ion is practically independent of its mass and the manner of its production. It may

vary with humidity in the case of the negative ion from about 1.8 cm/sec/v/cm to 1.3 cm/sec/v/cm. The mobility of this positive ion is practically independent of the humidity.[1] These results suggest that there should be no negative small ions in the atmosphere having a mobility less than 1.6 cm/sec/v/cm, nor positive small ions of mobility less than 1.2 cm/sec/v/cm. Results taken at random from published papers show too small mobilities as compared with laboratory-determined values. These mobilities were computed from the conductivity and ionic-content data. Since the conductivity is affected by only two or three per cent, owing to the presence of large ions, it is probable that their presence has affected the ionic-content results.

The three most commonly-suggested methods for determining the mobility of small ions in the atmosphere are: Method of Mache, method of Gerdien, and the indirect method, in which the mobility is computed from the conductivity and ionic content. The corrections for the presence of larger ions in the atmosphere is much smaller in the Gerdien than in the Mache method. Consequently, the Gerdien method was used by the authors in securing data on the corrected and uncorrected small ionic mobilities. The results show a mean uncorrected mobility of 0.53 and 0.81, respectively, for the positive and negative ions; the corresponding corrected values are 1.27 and 2.16.

The authors conclude that the mobilities obtained in the field do not correspond to those of any particular group of ions and accordingly are of little or no value. It is therefore hardly worth while, in their opinion, to carry out such experiments in the future.

The article is of value in that it may induce workers in this field to exercise more care in ascertaining the extent to which their ionic-content determinations are being affected by the presence of large ions. The importance usually attached to the results of ionic mobility determined in the field, especially by the indirect method, is considerably overemphasized by the authors.

Ionic content determined over the oceans, where there is a smaller number of large ions than over land, should consequently be less affected by this factor. Among the results selected by the authors by way of illustration are certain published mobility-data obtained on one of the early cruises of the *Carnegie*, which they assume to have been greatly affected by the presence of large ions. These particular data happen to be abnormal and cannot be taken as typical of either land or ocean-values. Therefore, they should not be used to illustrate this point. Evidence has been secured by the reviewer, all of which points to the fact that the *Carnegie* mobility-data are not appreciably affected by the presence of large ions. This evidence may be briefly given as follows: (1) The frequency-curve for the positive and the negative mobilities for data obtained on cruises IV, V, and VI shows no distortion at lower mobilities, as would be expected if large ions appreciably affected the results; (2) Disregarding some abnormally high values, the mean negative mobility, corrected for humidity on the basis of Erikson's recent finding is exactly what one would expect from laboratory results; (3) Using data from Cruise VII, the ionic-contents show no increase with increase in the number of Aitken nuclei; (4) The ion-counter, as used on the *Carnegie*, acts as an ion-counter for all ions having a mobility greater than about 0.1 cm/sec/v/cm and as a conductivity apparatus for ions of smaller mobility. In order to affect the ion-count by as much as 25 per cent, all the Aitken nuclei must be charged, either positively or negatively, which can hardly be the case.

G. R. WAIT

[1]In view of Erikson's recent results this last statement is open to question.

CHAPMAN, S. *On the radial limitations of the Sun's magnetic field.* London, Mon. Not. R. Astr. Soc., v. 89, 1928 (57-79).

It appears from observations that the Sun's magnetic field diminishes very rapidly with height. The author determines the radial limitations of the field after showing how the magnetic field proceeding from within the Sun and due to westward electric currents will set up eastward electric currents in the solar atmosphere after having also described certain properties of an ionized gas in the presence of a magnetic field. The results derived seem to establish at last a presumption in favor of his theory of a radial limitation.

The list of principal properties of the Sun's general magnetic field as observed at Mt. Wilson given in the first paragraphs, form a convenient reference.

The author's conclusions are given best in his own summary as follows:

(1) It is shown that the combined effect of the gravitational, electrostatic, and magnetic fields existing in the Sun's reversing layer will be to produce an eastward "drift-current" of electrons, and that this current is of the right order of magnitude to explain the radial limitation of the Sun's magnetic field. The theory sets a lower limit to the pressure at the base of the reversing layer, which is of the same order as, but slightly greater than, the value assigned on other grounds by E. A. Milne. The reduction of the magnetic intensity from 50 to 10 gauss probably occurs in a layer only about 25 km thick.

(2) It is shown that the observed rapid downward increase of intensity of the Sun's magnetic field probably continues to a depth of about 100 km below the photosphere, where the intensity rises to about 10,000 gauss.

(3) The drift-currents in the Sun's upper layer merely confine within the atmosphere tubes of magnetic force of internal origin, which would otherwise spread out into space. The internal field, the intensity of which, just below the drift-current layer, is between 3,000 and 4,000 gauss, must be produced by a system of westward electric currents in a deeper layer; the nature of the field between this region and the drift-current layer is described. The westward current system is attributed to electromagnetic induction by internal circulation of solar matter in meridian planes; it is shown that the orders of magnitude involved in this theory are not unreasonable, if the circulation is similar to that postulated by Bjerknes in his theory of the sunspot-cycle.

W. J. PETERS

KOENIGSBERGER, J.: *Ueber den Einfluss von Geländeunebenheiten auf das erdmagnetische Vertikalfeld.* Beitr. Geophysik, Leipzig, Bd. 20, Heft 3/4, 1928 (293-307). (Author's summary preceding article.)

The unevenness of a country has a topographical effect on the magnetic vertical intensity Z, similar to that encountered in gravity-determinations. In general, this effect cannot be deduced theoretically. An extreme positive and negative value for ΔZ (the additional vertical intensity) seems to be $\Delta Z = \pm 4\pi KZ$. ΔZ is for $K \leq 0.01$ almost proportional to K. In mountains of gneissic rocks (Bellinzona, Ticino, Switzerland) the greatest difference between summits (+) and steep valleys (−) was about 120γ. In the same gneiss there were large stone quarries at the base of mountains surrounding the large alluvial plain of the Ticino River. The vertical intensity in the immediate neighborhood of the wall of the quarry was about 40γ less than the average value in the plain at a distance of about 50 meters or more from the quarry. In the alluvial plain of the Rhine near Freiburg, Baden, Germany, there were several gravel pits. Observa-

tions made in the holes or at the edge of the holes yielded an effect of about -20γ as compared with the plain. In red sandstone of very small magnetic susceptibility no effect of quarry, slope, or tunnel could be detected. The effect is, as proved by the observations, proportional to K, increasing with the angle of the slope (under 30° there were for $K \leq 10^{-4}$ no appreciable effects) and should vary according to the situation of the wall with reference to the magnetic meridian; this, however, could not be observed. The topographical effect, therefore, permits the approximate calculation of the value of the susceptibility of large masses of rock in the Earth's magnetic field.

The observations were made with a vertical-intensity variometer which gives results with an accuracy of about $\pm 3\gamma$. The local inhomogeneity of the places where the topographical effect was studied was about $\pm 4\gamma$.

NOTES

(See also pages 38 and 54)

8. *Personalia*—Dr. *Elie van Rijckevorsel* died on October 18, 1928, at the age of eighty-three years. It will be recalled that he undertook in 1874 a magnetic survey of the East Indian Archipelago at his own expense, only the instruments being provided by the Dutch Government, and that between 1882 and 1885, he carried out a similar survey of Eastern Brazil with the assistance of E. Engelenburg. He also made the first and only magnetic survey of Holland. He was one of the pioneers of international research and was recognized as such by his nomination as one of the eight members of the first magnetic commission created at Paris by the International Meteorological Committee in 1896.

Prof. *Rudolf Spitaler*, Prague, celebrated on January 7, 1929, his seventieth birthday. On this occasion he was honored by a "Festschrift" edited by Prof. L. W. Pollak, to which a number of pupils and friends of Prof. Spitaler contributed scientific papers, particularly on geophysical subjects.

Dr. *C. A. Heiland*, professor of geophysics at the Colorado School of Mines, Golden, Colorado, gave a series of lectures in geophysical prospecting at Columbia University, during February and March of the present year. These courses comprised: Torsion balance, magnetometer, seismograph, and electrical prospecting.

Prof. *S. Chapman*, of the Imperial College of Science and Technology of London, has taken the place among the foreign collaborators of this Journal made vacant by the death of Dr. *C. Chree*.

Wallace M. Hill, Magnetic Observer of the U. S. Coast and Geodetic Survey, has taken over the work from *Clarence A. George* of carrying on magnetic surveys in the southeastern part of the United States.

Sir *Frederic Stupart*, director of the Meteorological Service of Canada, retired on January 1, 1929, after forty years of service.

Prof. *S. Chapman* has been appointed Rouse-Ball lecturer for the present year in the University of Cambridge.

Dr. *A. D. Power*, who was connected with the Department of Terrestrial Magnetism during 1912-1914, and 1916-1918, carrying out magnetic exploratory work in South America and taking part in Cruises IV and V of the "*Carnegie*," has resigned his position as professor of physics and director of radio research at Lawrence College, to conduct scientific research for the improvement of radio vacuum tubes at the Bloomfield, New Jersey, branch of the Westinghouse Lamp Company.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Aksenov, P. L'anomalie gravimétrique dans le domaine de Belgorod de l'anomalie magnétique de Koursk. Leningrad, Bull. Acad. sci., No. 1, 1928 (63-88 avec 3 fig. et 4 pls.). [Texte russe.]

Bartels, J. Sonnenflecken und Erdmagnetismus. Naturw., Berlin, Jahrg. 16, Heft 48, 1928 (1032-1033).

Bombay and Alibag Observatories. Magnetic, meteorological, and seismographic observations made at the Government Observatories, Bombay and Alibag, in the year 1923, under the direction of S. K. Banerji. Calcutta, Govt. India Central Publication Branch, 1928 (72 with 5 pls.). 34 cm.

Buenos Aires, Ministerio de Agricultura. Memoria correspondiente al ejercicio de 1927. Dirección de Meteorología. Buenos Aires, 1928, 26 pp. 27 cm. [Contains brief report on the work done in atmospheric electricity and terrestrial magnetism at the observatories of the Dirección de Meteorología during 1927.]

Chapman, S. On the radial limitation of the Sun's magnetic field. London, Mon. Not. R. Astr. Soc., v. 89, Nov., 1928 (57-79). Abstract: Observatory, London, v. 51, Dec., 1928 (360-361).

The Sun's general magnetic field and the chromosphere. London, Mon. Not. R. Astr. Soc., v. 89, Dec., 1928 (80-84).

Chapman, S., and T. L. Eckersley. Radio echoes and magnetic storms. Nature, London, v. 122, Nov. 17, 1928, p. 768. [Remarks on Prof. Carl Störmer's letter published in Nature, Nov. 3, 1928, p. 681.]

Grave, D. Evolution de l'influence de l'hyperatmosphère électrique sur le magnétisme terrestre. Leningrad, C. R. Acad. sci., No. 22, 1928 (455-456). [Texte russe.]

Greaves, W. M. H., and H. W. Norton. Magnetic storms and solar activity 1874 to 1927. London, Mon. Not. R. Astr. Soc., v. 89, Dec., 1928 (84-92).

Greenwich, Royal Observatory. Results of the magnetic and meteotological observations made at the Royal Observatory, Greenwich, and the Abinger magnetic station, Surrey, in the year 1926, under the direction of Sir Frank Dyson, Astronomer Royal. London, His Majesty's Stationery Office, 1928 (100 with 11 pls.). 30 cm.

Haalck, H. Zur Frage nach der Ursache von lokalen gravimetrischen und erdmagnetischen Störungen und ihre wechselseitigen Beziehungen. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 6, 1928 (263-272). [Es wird der theoretische Zusammenhang zwischen Schwerestörungen und lokalen erdmagnetischen Störungen kurz erörtert und gezeigt, wie man die Diagramme zur Bestimmung der Wirkung von Massenungleichheiten beliebiger Gestalt auf die Drehwaage auch verwenden kann für die Bestimmung der Wirkung dieser Massen auf die erdmagnetischen Kraftkomponenten. Die praktische Anwendung wird an einem Beispiel gezeigt.]

Hazard, D. L. Results of magnetic observations made by the United States Coast and Geodetic Survey in 1927. Washington, D. C., Dept. Comm., U. S. Coast Geod. Surv., Ser. No. 423, 1928, 22 pp. 23 cm.

Koenigsberger, J. Ueber den Einfluss von Geländeunebenheiten auf das erdmagnetische Vertikalfeld. Beitr. Geophysik, Leipzig, Bd. 20, Heft 3/4, 1928 (293-307).

KOWNER, S. S. Eine mathematische theorie der magnetischen Isogonen. Leningrad, Inst. Recherches Géophys., Bull. Géophys., No. 14, 1926 (41-46). [German text with Russian résumé.]

On an artificial example of lines of equal annual change. Leningrad, Inst. Recherches Géophys., Bull. Géophys., No. 14, 1926 (47-49). [Russian text with English abstract.]

KRAVEC, T. (T. KRAVETZ.) Sur les anomalies magnétiques. Leningrad, C.-R. Acad. sci., No. 22, 1928 (470-472). [Text russe.]

MÄDER, M. Bordgeräte im Verkehrsflugzeug. Berlin, Zs. Ver. D. Ing., Bd. 72, 1928 (1426-1434). Abstr. Zs. Instrumentenk., Berlin, Jahrg. 48, Dez., 1928 (621-623). [Contains description of a magnetic compass (Fernkompass) especially adapted for use on aircraft.]

MAGNETIC PHENOMENA. Magnetic phenomena in relation to the upper atmosphere and to solar activity. Observatory, London, v. 51, Dec., 1928 (374-378). [The above was the subject chosen for the "Meeting for the Discussion of Geophysical Subjects" held in the rooms of the Royal Astronomical Society, London, November 16, 1928. The principal speakers were S. Chapman, who discussed the portion of the diurnal magnetic variation which has its origin above the Earth, referring to the dynamo theory of Balfour Stewart and the recent theory of Ross Gunn for explaining the diurnal variation; W. M. H. Greaves, who spoke on the relationship of solar and magnetic phenomena, and E. V. Appleton, who considered the subject from the standpoint of wireless telegraphy.]

POLLAK, L. W. Das Periodigramm der internationalen erdmagnetischen Charakterzahlen. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 6, 1928 (289-294).

RAMOS DA COSTA, A. A polaridade magnetica das manchas solares e a sua influencia na terra. Asoc. Esp. Prog. Ciencias, Sect. 2, Astron. Fís. del Globo, Cádiz, 1927 (25-31).

RIO DE JANEIRO, OBSERVATORIO NACIONAL. Annuario publicado pelo Observatorio Nacional do Rio de Janeiro para o anno de 1929. Anno XLV. Rio de Janeiro, Imprensa Nacional, 1928 (xvi + 292 com 2 mappas). 18 cm. [Contains tables of magnetic declination at various points in Brazil reduced to epoch 1929.0 and an isogonic map of Brazil for September 1922.]

SAN FERNANDO. Anales del Instituto y Observatorio de Marina publicados de orden de la Superioridad. Sección 1. Observaciones meteorologicas, magnéticas y sismicas. Año 1927. San Fernando, 1928 (v+88 con curvas). 34 cm.

SCHMIDT, AD. Der Stand der erdmagnetischen Forschung. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 6, 1928 (294-304). [Es wird der Stand unserer Kenntnis von dem beharrlichen Hauptteil des erdmagnetischen Feldes und der Säkularvariation, von den periodischen Schwankungen und von den Störungen und der Nachstörung besprochen und auf die in bezug hierauf bestehenden Probleme hingewiesen. Dabei zeigt sich überall der hemmende Einfluss, den die ungenügende Anzahl und noch mehr die sehr ungünstige Verteilung der magnetischen Observatorien ausübt, so dass eine planmässige Vervollständigung des Netzes dieser Anstalten als wesentliche Vorbedingung weiteren Fortschritts erscheint.]

SCHUH, FR. Magnetische Anomalien im westlichen Mecklenburg. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 6, 1928 (304-313 mit 2 Abb.).

SPRARAGEN, L. Magnetometer survey of Oklahoma. Oil and Gas J., Tulsa, Okla., v. 27, 1928, Nov. 1 (33, 102); Nov. 8 (37, 159-160); Nov. 15 (42, 108-109).

TONTA, L. A new type of polar chart. Method of navigating in the polar regions with the magnetic compass. Hydrogr. Rev., Monaco, v. 5, No. 2, Nov., 1928 (51-60).

TURCEV, A. Investigations of the magnetic properties of rocks. Leningrad, Bull. Acad. sci., No. 1, 1928 (89-112).

UNITED STATES COAST AND GEODETIC SURVEY. Annual report of the Director, United States Coast and Geodetic Survey to the Secretary of Commerce for the fiscal year ended June 30, 1928. Washington, D. C., Dept. Comm., U. S. Coast Geod. Surv., 1928 (47 with 17 maps). 23 cm. [Contains general account of the magnetic and seismic work for the period in question.]

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B—Terrestrial and Cosmical Electricity

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Terrestrial Magnetism *and* *Atmospheric Electricity*

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TILTING DEVIATIONS IN MAGNETIC DECLINATIONS

BY WILLIAM J. PETERS

Abstract—Experiments were made by swinging compasses in a wooden swing for the purpose of investigating deviations caused by the ship's rolling motion. Results obtained with various types of compasses are submitted in two tables. Dynamic deviations, the kinetic equilibrium error, and conditions other than those considered in these two theories are briefly discussed. Equations are given for computing the direction and relative strength of the apparent gravitational field as affected by the accelerations of the rolling motion. These are used to determine the maximum angle of tilt produced by the maximum angle of roll. The kinetic equilibrium error for an angle of tilt in one direction is shown to be different for an equal angle of tilt in the opposite direction for certain elements in certain directions of the axis of tilting and hence give rise to deviations. Examples are given for the three magnetic elements for instantaneous values of tilting. The computed deviation in declination that results in the case of a magnet having large moment of inertia, constrained to move about an axle parallel to the radius of swing, and having considerable damping has been found to be much smaller than would be indicated by the results of the experiments for the same conditions. It is concluded that this theory of tilting deviations does not account for the whole deviation observed and must be regarded as only contributing a part of the effect as does also the theory of dynamic deviations.

If a ship's compass is mounted in a swing constructed of wood or rigid non-magnetic parts and constrained to move like a pendulum in a vertical plane without twisting, oscillations of the compass-card[1] will usually be seen and the following facts may be observed:

(*a*) When the vertical plane of the swing's motion is N-S, that is, if the axle of the swing is E-W, the oscillations will be small if indeed there be any, and the mean reading of the lubber-line will not differ materially from the mean reading when at rest.

(*b*) When the axle is lying N-S, oscillations are usually seen, sometimes quite large, but the mean reading again is nearly the same as at rest.

(*c*) When the axle is lying in any other direction, and notably in an intercardinal direction, the mean reading of the lubber-line when the swing is in motion will usually differ from the readings

[1] The expression "compass-card" or the "card" in this paper means, unless otherwise stated, the whole assembly of card, cap, magnet, float, etc., that is suspended upon the pivot, and the magnetic axis of the system is assumed to lie in the plane of the card or in a plane parallel thereto.

taken when the swing is at rest, and hence give rise to deviations which seem to be fairly permanent so long as the amplitude of the motion of the swing remains constant.

(*d*) The deviations for axle NE-SW will have an opposite sign to the deviation for axle SE-NW.

(*e*) The sign of the deviation and its magnitude are peculiar to each compass.

(*f*) The magnitude of the deviation and the amplitude of the card[1] oscillations increase with the amplitude of the swing and the radius.

Deviations in the same direction, that is, of the same sign, are observed when the compass is swung below the axle of the swing, or above the axle, or when it is mounted in a swing of the type of a child's rocking horse, provided the axis has the same direction in each case. It is therefore concluded that such quasi-permanent deviations, that is, deviations that persist in direction, though perhaps varying in magnitude, are produced by the rolling motion of a ship, even though this motion is generally more forced and more damped than the motion of the swing.

In view of the magnitudes of the deviations shown by experiments, examples of which are tabulated further on, it might be stated here that deviations produced by the ship's motion in the results of observations made with a good compass, and distributed over a time-interval of twenty minutes at least, are seldom more than one degree; more likely they are less than one-half or one-third, for a vessel of the size of the *Carnegie*. These limits may be inferred from the degree of concordance that is found in the results for neighboring stations at sea as well as in the differences between the observed declinations and charted declinations over more extensive areas. They are confirmed to some extent by consideration of the differences between the conditions of experiment and those at sea.

Experiments were made in a swing (see Fig. 1) built of wood, fastened with copper and brass, having one platform which remains continuously level during oscillations of the swing (parallel swing) and another (tilting swing) which, being rigidly attached to one of the uprights, will tilt at an angle always equal to that of the swing from its position of rest. The apparatus is suspended from the beams of the ceiling of the Department's standardizing observatory, which has been constructed of material free from magnetic properties. The fastening through the ceiling is arranged so that the plane of swing-oscillations can be shifted into any azimuth required for the experiment. The two upright hanging pieces at each end of the platform are braced against any movement out of the plane of oscillation. The platform rests on brass axles with non-magnetic ball-bearings through the lower ends of the uprights, which in turn are suspended by similar axles through their upper ends. Intermediate bearings permit of shortening the radius of swing.

Peep-sights on the horizontal tie-pieces are used to set the swing accurately into the required azimuth by sighting on marks drawn

FIG. 1—Wooden swing with liquid compass on tilting platform

on the walls of the building, after which the upper structure is securely blocked by wedges and clamped.

The oscillations are usually started and maintained by pulling

on a cord leading from eyes in the swing to small fair leads or pulleys screwed into the wall. The amplitudes of the oscillations can be read on a graduated arc divided into single degrees cut in a

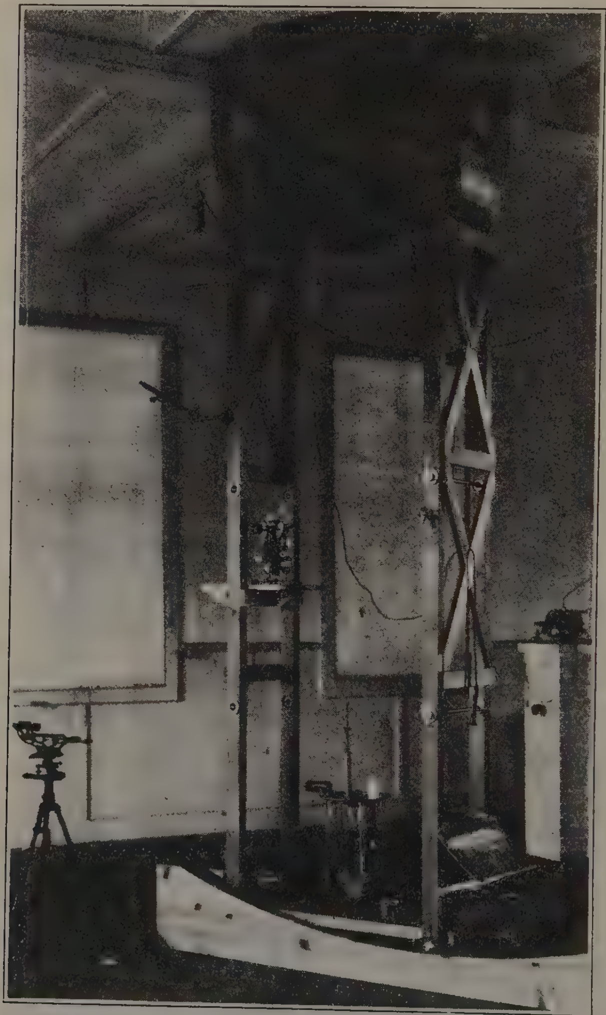

FIG. 2—Wooden swing with theodolite on upper tilting platform and telescope on tripod

wooden board resting on edge and movable on the floor. They are assumed to be constant during an experiment, but with the arrangement shown, they could not be maintained closer than one-half degree. For certain experiments more accurate determina-

tions of a fixed inclination of the swing were made with a theodolite mounted on an upper platform (see Fig. 2), having a vertical circle and a level attached to the telescope.

Various optical arrangements were used on different occasions. The lubber-line reading of a compass mounted on the tilting platform was usually made by the aid of a telescope attached close to one of the upper axles, a collimating lens, and a mirror (not shown) mounted close to the center of the glass cover of the compass. His head being then near the center of motion, the observer could see the field of view continuously throughout an oscillation with very little moving of his head. A compass on the horizontal platform, or parallel swing, was read through a large reading glass which enabled the observer, reclining in the plane of the swing's motion, to see the graduations continuously by moving his head up and down through a small vertical range.

A fixed telescope with a graduated reticule occasionally was mounted on a small tripod on the floor in the plane of the swing's motion (Fig. 2) and sights taken through a collimating lens fixed on the horizontal platform. Although the range in arc of oscillation at which readings could be made was limited to those portions at which the collimating lens was approximately at the level of the telescope, still it was found useful in detecting and measuring any twist of the swing while in action as it passed from one extreme to the other, and also in making certain adjustments.

The top surface of the platform in parallel swing is 2.78 meters below the center of motion when the swing is in its position of rest or equilibrium. The tilting platform is 2.64 meters below the center of motion. The period of two successive transits of the pointer in the same direction across the zero of the arc is 3.22 seconds, when the swing is loaded with 100 pounds of pig lead and a 7½-inch liquid compass cardanically suspended in its carrying case. The substitution of other compasses does not change the period a tenth of a second. The length of the equivalent simple pendulum is $l = T^2g/4\pi^2 = 2.57$ meters. A compass in cardanic suspension placed either on the tilting platform or on the horizontal platform will oscillate in phase with the swing and with very nearly the same amplitude.

Table 1 shows the deviations observed in the earliest experiments (1922) with various compasses mounted on the experimental swing and subjected to prolonged swinging at various selected amplitudes from 1° to 17°, inclusive. The lubber-line was read before and after the set, and from this mean was subtracted the mean of ten readings made when the card appeared fairly steady on reaching each selected maximum amplitude of the program from 1° to 17°.

Observations were then repeated in the reverse order of decreasing amplitude of swing-oscillations 17° to 1°. The time taken for each compass varied somewhat at first, but was finally increased to about one hour.

TABLE 1—*Deviations produced by harmonic motion of rigidly suspended swing with axle NE-SW*
(Deviation to east +, to west −)

No.	Instrument	Radius	Period[a]	Date	Maximum amplitude of swing				
					1°	3°	6°	11°	17°
		m	*s*	*1922*	°	°	°	°	°
1	Ritchie compass 39670	2.64	30	Aug. 24	+0.10	+0.35	+1.25	+3.8	+ 7.4
2	" " "	2.64	30	26	+0.25	+0.49	+1.73	+4.41	+ 6.78
3	" " "	2.48	30	30	0.00	+0.14	+1.20	+3.32	+ 5.76
4	" " "	2.64	30	30	+0.02	+0.23	+1.14	+3.58	+ 6.40
5	Ritchie compass 31974 (Negus)	2.64	32.2	26	+0.05	+0.13	+0.17	+0.50	+ 1.70
6	" " " "	2.64	32.2	Sep. 1	0.00	+0.04	+0.07	+0.40	+ 1.05
7	Ritchie compass 29499	2.64	42	Aug. 31	+0.04	+0.98	+2.55	+5.65	+ 7.33
8	C. I. W. Deflector 3	2.48	35	30	+0.05	+0.24	+1.60	+3.34	+ 4.52
9	Thomson compass-card 13845	2.60	22.5	26	+0.03	+0.04	+0.08	+0.20	+ 0.44
10	" " " "	2.60	22.5	28	+0.03	+0.06	+0.11	+0.29	+ 0.56
11	" " " "	2.60	22.5	28	+0.04	+0.09	+0.21	+0.36	+ 1.16
12	" " " "	2.60	22.5	28	+0.04	+0.08	+0.10	+0.29	+ 0.77
13	" " " "	2.60	22.5	Sep. 1	0.00	0.00	+0.04	+0.19	+ 0.83
14	Thomson compass-card 7784	2.60	35.5	1	0.00	−0.10	−0.39	−1.00	− 2.02
15	Thomson compass-card 14148	2.60	30	1	0.00	−0.12	−0.22	−0.73	− 1.66
16	Wilcox-Crittenden boat-compass D-186	2.79	16.0	Aug. 24	+0.10	......	−1.1	−3.0	− 5.0
17	" " " " " "	2.79	16.0	29	+0.01	−0.09	−0.42	−1.84	− 3.94
18	" " " " " "	2.79	16.0	Sep. 5	−0.01	0.00	−0.28	−1.38	− 5.06
19[b]	" " " " " "	2.79	16.0	5	+0.02	−0.04	−1.26	−6.28	−12.43
20[b]	" " " " " "	2.79	16.0	6	0.00	−0.26	−0.61	−1.96	− 3.84
21	Durkee boat-compass S-872	2.70	13	Aug. 30	0.00	−0.56	−1.35	−2.68	− 8.16
22[c]	" " " " "	2.70	13	31	0.00	0.00	−0.61	−3.64	− 8.51
23[d]	" " " " "	2.70	13	Sep. 1	0.00	−0.05	−0.05	−3.3	− 7.9
24[e]	" " " " "	2.70	13	2	0.00	−0.05	−0.40	−2.50	− 5.55
25	Durkee boat-compass S-1262	2.70	19.8	Aug. 29	0.00	−0.24	−0.84	−3.28	− 7.74

[a] Approximate for H = 0.186 *c. g. s.* [b] Center gimbal motions and top of pivot all in same plane. [c] Weight added to south end before this set. [d] Card balanced before this set. [e] Final balance made before this set.

The oscillations of the card of a compass which is constrained to regular oscillatory motion about a fixed axis are explained by three conditions: (*a*) The position of the center of mass of the card and magnets not coinciding with center of suspension; (*b*) a centrifugal couple arising from differences in radii of each elementary mass of the card about the axis of rotation; (*c*) changes in the magnetic couples arising from the tilting of the card. Deviations occur when the amplitudes of these oscillations are greater or tend to be greater on one side of the position of normal equilibrium than on the opposite. Conditions (*a*) and (*b*) will be considered briefly; (*c*) is the subject of this paper.

(*a*)—The errors of magnetic instruments that might be persistently produced by the motion of a ship at sea were investigated by Bidlingmaier[2] under the assumption that the ship rolls, pitches or rises and falls with a simple harmonic motion, and that the center of gravity of the magnetic needle or system of magnetic needles does not coincide with the point of suspension. He also assumes during the course of his investigation that the plane of free motion of the magnet remains fixed in direction, that is, always horizontal in the case of a compass, always vertical in the case of a dip circle, and also that the motion is not damped. He has given the name of dynamic deviations to such errors.

Applying Lagrange's equation of motion to the ship and to the compass on board, Bidlingmaier deduces a general expression for the deviation, δ, in the form of five factors

$$\delta = \mathbf{N} \times \mathbf{S} \times \mathbf{I} \times \mathbf{P} \times \mathbf{L}$$

which he designates as the numerical, the ship, the instrument, the period and the position factor.

For the ordinary compass as distinguished from the card deflected in horizontal-intensity determinations[3] these factors become $\mathbf{N}=\mathrm{N}$, $\mathbf{S}=(Ae/P)^2$, $\mathbf{I}=(Ml/mH)^2=(mZ/gmH)^2=(\tan\ I/g)^2$, $\mathbf{P}=1/(P^2-p^2)$, $\mathbf{L}=\sin 2\zeta$ and δ is expressed in degrees. The notation is as follows A = roll of ship, i. e., inclination from upright position; e = distance between compass and axis of roll; P = twice the ship's period as usually stated; I = magnetic inclination or dip; g = acceleration of gravity; l = distance between center of gravity of compass-card and point of suspension; m = magnetic moment of the compass-card; M = mass of the compass-card; H = horizontal component of Earth's magnetic field; Z = vertical component of Earth's magnetic field; p = time of a double oscillation of the compass-card; ζ = the magnetic course or heading.

[2] BIDLINGMAIER, F., Deutsché Südpolar Expédition, 1901-1903, Bd. V; Erdmagnetismus, Bd. I, Heft 2, I. Teil (273-309). Berlin, 1909.

[3] Representing the angle of deflection of the deflected card by u, and the dynamic deviation in u by δu expressed in degrees, $\delta u = \mathbf{N} \times \mathbf{S} \times \mathbf{I} \times \mathbf{P} \times \mathbf{L}$. The numerical and the ship-factors are the same as for the undeflected card, but $\mathbf{I}=(\tan I \sec u/g)^2$, $\mathbf{P}=1/(P^2-p^2) \sec u$, and $\mathbf{L}=\cos 2\zeta \sin 2u$. In this case p is still the time of a double oscillation of the *undeflected* card. The deviation δu is a maximum on the cardinal headings and is zero on intercardinal headings. The observed value of u uncorrected for δu is larger on north and south headings, and smaller on east and west headings than the normal values if $p>P$.

The periods P and p are the times elapsed between two successive transits in the same direction through the position of equilibrium. The deviation becomes zero when A, e, I, or sin 2ζ is equal to zero.

For Ritchie compass 39670 in the experimental swing just described, the five factors become in *c. g. s.* units and with angular measure expressed in degrees; $\mathbf{N}=6.8$; $\mathbf{S}=(11^\circ\times 264/3.2)^2=80\times 10^4$; $\mathbf{I}=(2.946/980.6)^2\doteq 9\times 10^{-6}$; $\mathbf{P}=1/(3.2^2-30^2)=11\times 10^{-4}$; $\mathbf{L}=\sin(2\times 45^\circ)=1$; and $\delta=-0^\circ.05$. The negative sign of δ means that the magnet is drawn toward the beam, that is, westerly deviation, contrary to the observed deviation for this compass given in Table 1, in which positive deviation is reckoned toward the east. The magnitude of the deviation observed is 70 times greater than the computed.

For convenience of reference Bidlingmaier's conclusions for both compass and dip circle are repeated here.[4]

"1. ***** Die dynamische Deviation ist proportional dem Quadrat der mittleren absoluten Geschwindigkeit, welche der Beobachtungsplatz an Bord infolge der Schiffsschwankungen erhält.

"2. ***** Die dynamische Deviation eines frei schwingenden Körpers ist proportional dem Quadrat der Exzentrizität seines Schwerpunkts und umgekehrt proportional dem Quadrat seiner Direktionskraft.

"3. ***** Die dynamische Deviation ist um so geringer, je verschiedener die Schwingungsdauern von Schiff und Nadel voneinander sind und je langsamer dabei die beiden Schwingungsarten sich abspielen.

"4. ***** Die dynamische Deviation erreicht ihr Maximum: bei der Horizontalnadel, wenn diesselbe unter 45° gegen die Mittschiffslinie, bei der Inklinationsnadel, wenn diesselbe unter 45° gegen die Vertikale geneigt ist; sie verschwindet: bei der Horizontalnadel, wenn sie längsschiffs oder querschiffs. bei der Inklinationsnadel, wenn sie wagrecht oder senkrecht steht.

***** Das Vorzeichen von -2ϵ ist daher das Vorzeichen von δ und entscheidet über den Sinn der dynamischen Deviation. Wenn wir uns mit der oben wiedergegebenen Bedeutung von ϵ die einzelnen Fälle überlegen, so ergibt sich unter der Voraussetzung, dass die Nadel schneller schwingt als das Schiff, folgendes Resultat: die Horizontalnadel wird stets nach längsschiffs abgelenkt, die Inklinationsnadel wird beim Rollen stets nach der Vertikalen, bei den Vertikalschwankungen des Schiffs stets nach der Horizontalen abgelenkt.

"5. ***** Die dynamische Deviation ist unabhängig von dem Schwingungszustand der Nadel an Bord; sie tritt insbesonders auch dann ein, wenn die Nadel an Bord nur wenig oder gar nicht schwingt. *****"

On any one heading the dynamic deviation in declination will change sign only when the period-factor changes sign. No compass used in the experiment, Table 1, has a period so small as 2×1.6 seconds, the full period of the swing, yet the deviations in the lower part have opposite signs to those in the upper.

The discrepancies between the deviations observed in the swing and the dynamic deviations computed for the swing are probably explained by the ignoration of conditions (b) and (c).

(b)—Centrifugal couples may arise even for a magnet perfectly balanced about each axis of symmetry when it is mounted on ship or swing which is constrained to harmonic motion about a

[4] BIDLINGMAIER, F., Erdmagnetische See-Beobachtungen. I. Teil, Die Grundlagen (297-298).

horizontal axle. The problem has not been investigated, and hence the following conditions are merely stated by way of suggestion.

If the horizontal axis of harmonic motion of ship or swing is in the same vertical plane as the magnetic axis and the principal axis of least moment of inertia, and if that principal axis be inclined to the horizontal axis of harmonic motion of the ship or swing, then there is evidently a centrifugal couple acting to increase the inclination brought about by longer radii to one-half the principal axis than to the other half. This couple may be resolved into components and one being taken in the plane in which the card is free to move would induce oscillations of the card.

If two aluminum rods of equal mass and length be assembled as a straight line on the pivot of a Thomson dry compass mounted in the wooden swing and be allowed to come to rest, then when the swing motion is started this non-magnetic needle will orient itself at right-angles to the axis of swing. If two more rods of equal mass and length are added at right-angles to the assembly so as to form a cross, no change in orientation takes place even after prolonged swinging. This experiment seems to indicate that the existence of axes of maximum and minimum inertia plays a rôle, though other conditions such as the position of the center of mass above or below the point of suspension and friction at point of suspension may also enter. The moments of ordinary navigational compasses may be considered for practical purposes as equal about any horizontal axis so far as regards the graduated card, the buoyant chamber and other parts having their horizontal sections circular, but this equality of moments is frequently destroyed by the distribution of the magnets. The horizontal axis of least moment of inertia of the magnet or assembly of magnets generally coincides in direction with the direction of the magnetic axis. The excess of the maximum moment over the minimum moment in the assembly of magnets is very different in various types of compasses, although the difference might not be very conspicuous in a casual inspection.

The distribution of the four cylindrical tubes of magnets in compass Ritchie 29499 is apparently not very different from that of the four flat magnets of boat compass Wilcox-Crittenden D-186, but the ratio of the difference of greatest and least moments of the assembly of magnets to the sum of the moments is $+0.16$ for Ritchie 29499 and $+0.70$ for Wilcox-Crittenden D-186, the positive sign meaning that the axis of least moment is parallel to the magnetic axis.

(*c*)—Oscillations of the card caused by the tilting of the plane of the card were investigated by Sir William Thomson, who called them the kinetic-equilibrium error. He defines the position of kinetic equilibrium of the compass at any instant as the position in which it would rest under the magnetic forces and a force of *apparent gravity* whose acceleration is equal to the resultant of gravity-acceleration and the accelerations taken in opposite sense

of the cardanic suspension due to the rolling of the ship.[5] Starling has shown that the compass in an aeroplane has deviations when the plane is banking.[6] These errors or deviations arise from the same cause, a component of the Earth's magnetic field perpendicular to the plane of the magnetic meridian lying in the plane of free motion which is tilted from the horizontal by the accelerations of the rolling ship or changes in the speed or direction of the aeroplane.

There is, however, an important difference between the deviation of a compass tilted in an aeroplane and that of a compass on a rolling ship. In the aeroplane it is produced by a gradual tilting of the plane of apparent level as the aeroplane turns or changes speed. On a ship it is produced by oscillatory tilting as the ship rolls from side to side, and if the deviations were numerically equal, but of opposite sign for equal but opposite angles of tilt, they would disappear in the mean of observations extending over many compass-oscillations or they would be damped out in an instrument of a very long period as compared with the period of tilting. But they are not numerically equal except when the axis of tilting is in the plane of the magnetic meridian, a fact that Sir William Thomson does not take into account. When the axis of tilting is perpendicular to the plane of the magnetic meridian there is no component of the Earth's field in the tilted plane of free motion perpendicular to the plane of the magnetic meridian.

Since it is not convenient to measure the angle of tilting of a compass-bowl subjected to the rolling motion of a ship or the pendulum-motion of a swing, it will be calculated in this investigation from the angle of roll of the ship or the amplitude of vibration of the experimental swing by the method described by Pollard and Dudebout[7] for finding the direction and magnitude of apparent gravity of a point in a ship rolling in non-resisting medium and having no vertical motion. The period of the ordinary compass-bowl being less than one-fifth second, the bowl follows the changes in apparent gravity with little or no superimposed oscillations and the card remains practically in the plane of the shifting apparent level.

Let $Ga=r$ of Figure 3 be the radius of a point a, turning about a fixed axis G, making an angle α with the direction GZ of the true vertical considered downwards. The angle α is considered positive in the direction shown in the figure which represents a section perpendicular to the axis of rolling, as seen when looking forward. At the instant t the point a is in a' and its radius Ga' makes an angle, ρ with Ga positive in the direction indicated, which accordingly means a roll to starboard. The angle ρ is given by the equation

$$\rho=R \sin nt \qquad (1)$$

[5] Mathematical and physical papers, v. IV (464).

[6] *Phil. Mag.*, Ser. 6, v. 32, 1916 (461).

[7] POLLARD, J., ET A. DUDEBOUT, Théorie du navire, Tome II (301 *et seq.*).

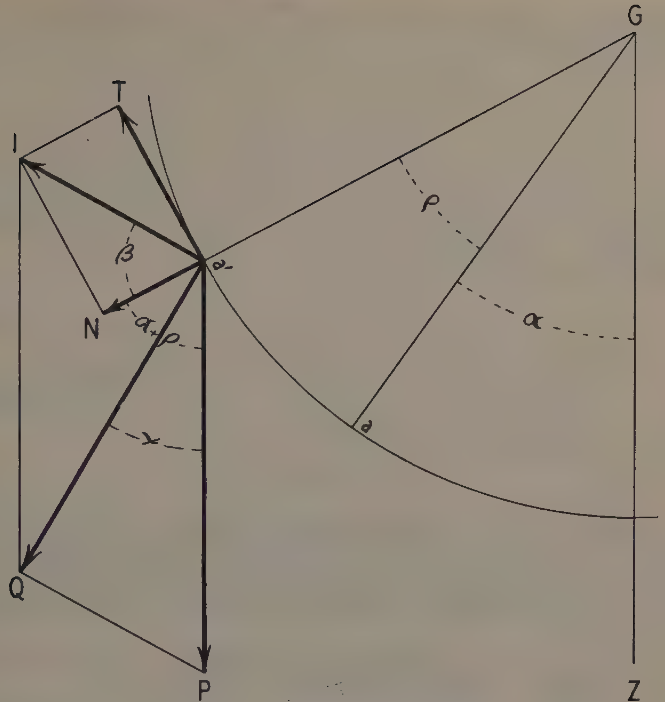

FIG. 3—Diagram of vectors representing rolling and gravity accelerations

in which R is the extreme amplitude, and $t=0$ when $\rho=0$. The full period is

$$T=2\pi/n \tag{2}$$

At the point a' the arc described by the moving point a on its circle is

$$s=r\rho=rR\ \sin\ nt$$

its linear velocity is

$$v=r(\mathrm{d}\rho/\mathrm{d}t)=rnR\ \cos\ nt=rn\sqrt{R^2-\rho^2}$$

The accelerations of inertia are

$-j_t=rn^2\rho$, tangential, directed away from position of rest
$-j_c=rn^2\ (R^2-\rho^2)$, centrifugal, directed away from the axis of rotation

The resultant of these accelerations, represented in the figure by $a'I$, makes an exterior angle β with the radius Ga' prolonged, and may be combined with the acceleration of gravity represented in the figure by $a'P$, the direction of which makes an interior angle $(\alpha+\rho)$ with the radius Ga' prolonged. The final resultant which

represents the apparent force of gravity at the point a' makes an angle ψ with the true vertical GZ given by the equation

$$\tan\psi = \frac{\rho\cos(\alpha+\rho)+(R^2-\rho^2)\sin(\alpha+\rho)}{g/rn^2+(R^2-\rho^2)\cos(\alpha+\rho)-\rho\sin(\alpha+\rho)} \tag{3}$$

This equation shows that $\psi=\alpha+\rho$ when $g\sin(\alpha+\rho)=rn^2\rho$, that is, the direction of apparent gravity will coincide with the direction of the radius Ga' when $g\sin(\alpha+\rho)$ is equal to the tangential acceleration. If λ represents the length of the simple pendulum corresponding to the period T, then

$$n^2=g/\lambda$$

and

$$r=\lambda\frac{\sin(\alpha+\rho)}{\rho}=\lambda\left(\frac{\cos\alpha\sin\rho}{\rho}+\frac{\cos\rho\sin\alpha}{\rho}\right)$$

which for small values of ρ becomes

$$r=\lambda(\cos\alpha+\sin\alpha/\rho)$$

If the point a is in the vertical under or over the axis G, then $\alpha=0$ and $r=\lambda$. As already stated, the length of the equivalent simple pendulum for the experimental swing is 2.62 meters. If the point a is in the vertical under the axis G then $\alpha=0$ and equation (3) becomes

$$\tan\psi = \frac{\rho\cos\rho+(R^2-\rho^2)\sin\rho}{g/rn^2+(R^2-\rho^2)\cos\rho-\rho\sin\rho} \tag{4}$$

If the point a is in the vertical over the axis G, then $\alpha=180°$ and equation (3) becomes

$$\tan\psi = \frac{-\rho\cos\rho-(R^2-\rho^2)\sin\rho}{g/rn^2-(R^2-\rho^2)\cos\rho+\rho\sin\rho} \tag{5}$$

For the maximum value of $\rho=R$

$$\tan\Psi=\frac{R\cos R}{g/rn^2-R\sin R}\text{ under axle}$$

$$\tan\Psi=\frac{-R\cos R}{g/rn^2+R\sin R}\text{ over axle} \tag{6}$$

Where Ψ is the maximum amplitude of the oscillations of the direction of apparent gravity and as the compass bowl usually has a very small period, this value of Ψ represents very closely the maximum angle of tilt.

The angle of tilt Ψ computed by (6) is given in Table 2 for different radii of the experimental swing and for the locations of the four magnetic instruments on the *Carnegie*. A comparison of values in the same column of oscillation of swing and roll of ship

is some confirmation that smaller deviations are to be expected in actual sea observations than the observed deviations of Table 1 if these deviations increase with the angle of tilt regardless of angle of roll.

TABLE 2—*Tilt* Ψ *corresponding to oscillation of swing or roll of ship R* ($g=9.806$ m/s^2)

Apparatus	r	T	R 5°	10°	15°	20°	25°
	m	*s*	°	°	°	°	°
Experimental swing	2.5	3.22	+4.7	+ 9.6	+14.4	+19.4	+24.6
	2.6	3.22	+5.0	+10.0	+15.0	+20.2	+25.6
	2.7	3.22	+5.2	+10.3	+15.6	+21.0	+26.7
Instruments on Carnegie							
Standard compass	2.2	7.0	−0.9	− 1.8	− 2.6	− 3.3	− 4.0
	2.2	7.5	−0.8	− 1.5	− 2.3	− 2.9	− 3.5
	2.2	8.0	−0.7	− 1.4	− 2.0	− 2.6	− 3.1
Dover gimbal-stand	3.8	7.0	−1.6	− 3.0	− 4.4	− 5.6	− 6.7
	3.8	7.5	−1.4	− 2.7	− 3.9	− 4.9	− 5.9
	3.8	8.0	−1.2	− 2.3	− 3.4	− 4.4	− 5.2
Deflector	4.0	7.0	−1.6	− 3.2	− 4.6	− 5.9	− 7.0
	4.0	7.5	−1.4	− 2.8	− 4.1	− 5.2	− 6.1
	4.0	8.0	−1.3	− 2.5	− 3.6	− 4.6	− 5.4
Marine collimator	5.5	7.0	−2.2	− 4.4	− 6.3	− 8.0	− 9.4
	5.5	7.5	−2.0	− 3.8	− 5.5	− 7.0	− 8.3
	5.5	8.0	−1.7	− 3.4	− 4.9	− 6.2	− 7.3

Under certain conditions the angle α may differ from 0° or 180° even when the instrument is in the sheer plan, as when the vessel is heeled and rolling at the same time. The effect is best shown by taking an unusual amount of roll and heel, say, from 0° to 20° starboard. In this case $\alpha=190°$, $R=10°$ and $\rho=\pm 10°$. Let $T=7.5$ secs., $g=9.806$, $r=4$ meters, then

$$\tan\psi_{+10}=\frac{0.1745\cos 200°}{3.493-0.1745\sin 200°}=\tan -2°.64$$

$$\tan\psi_{-10}=\frac{-0.1745\cos 180°}{3.493+0.1745\sin 180°}=\tan +2°.86$$

When, however, the vessel is rolling only 3° one way and 7° the other, which is not unusual, ψ_{+5} and ψ_{-5} do not differ numerically as much as 0°.1.

For convenience of future reference the relative magnitude of apparent gravity is also deduced. Denote the total acceleration of inertia by

$$w=(j^2_t+j^2_c)^{1/2}=[r^2n^4\rho^2+r^2n^4(R^2-\rho^2)^2]^{1/2}$$

and the resultant $a'Q$ which represents (Fig. 3) the magnitude of apparent gravity by g_ρ, then

$$g^2_\rho = g^2 + w^2 + 2gw\cos(\beta+\alpha+\rho) = g^2 + r^2n^4\rho^2 + r^2n^4(R^2-\rho^2)^2 + 2g[r^2n^4\rho^2 + r^2n^4(R^2-\rho^2)^2]^{1/2}[\cos\beta\cos(\alpha+\rho) - \sin\beta\sin(\alpha+\rho)]$$

Substituting the values of

$$\cos\beta = \frac{j_c}{\sqrt{j^2_t + j^2_c}} = \frac{R^2-\rho^2}{\sqrt{\rho^2 + (R^2-\rho^2)^2}}$$

$$\sin\beta = \frac{j_t}{\sqrt{j^2_t + j^2_c}} = \frac{\rho}{\sqrt{\rho^2 + (R^2-\rho^2)^2}}$$

there results

$$g^2_\rho = g^2 + r^2n^4\rho^2 + r^2n^4(R^2-\rho^2)^2 + 2grn^2[(R^2-\rho^2)\cos(\alpha+\rho) - \rho\sin(\alpha+\rho)]$$

As an example, take $T=7.5$ s, $g=9.806$ m/s², $r=4$ m, $\alpha=180°$, $R=10°$, then for $\rho=10°$, $g_{10}=9.903$ m/s², and for $\rho=0$, $g_0=9.721$ m/s².

Before leaving this particular subject it might be well to note that in the case of a ship at sea the axis of motion itself is usually subject to harmonic motion, and consequently the direction of apparent gravity even at the axis of rolling or the axis of pitching may not coincide exactly and continuously with the true gravitational vertical.

Figure 4 is a stereographic projection upon the plane of the horizon, *NBQSAP*, with the zenith as the point of sight. The line $N_\psi NS$ is the trace of the vertical plane of the magnetic meridian which passes through the nadir projected to *C*. The line *AB* is the projection of the axis of roll or tilt, assumed to be horizontal and to coincide in direction with the axis of tilt, so that if *B*, in the horizon, is the direction of the vessel's bow, the arc *NB* represents the ship's heading (magnetic), reckoned eastward from north. The tilt of the compass is shown downward to starboard, the direction of the apparent vertical (downward) having shifted through an angle ψ under the action of accelerations from its truly vertical direction *O* to O_ψ, and the plane of apparent level, that is, the plane in which the compass card is free to move having tilted from the trace *BNPA* to the trace $BN_\psi P_\psi A$ upward in the northwest (therefore outside of the primitive circle) and from *QSA* to $BQ_\psi S_\psi A$ downward in the southeast.

Let ζ = the arc, *BN* = the ship's heading; ζ_ψ = the arc, BN_ψ = the ship's heading by the inclined card; ψ = the angle, NBN_ψ = the angle of starboard tilt of the compass-bowl at the instant under consideration; a = the arc, NN_ψ = the vertical angle between the horizon and the intersection of the two planes $NN_\psi OS$ and BN_ψ

$P_\psi A$; and b = the angle, $NN_\psi B = P_\psi N_\psi O$, the inclination of the tilted card to the vertical plane of the magnetic meridian.

The relations of the elements of the spherical triangle NBN_ψ are given for ready reference:

$$\left.\begin{array}{ll}
\sin b = \dfrac{\sin \zeta}{\sin \zeta_\psi} & \sin \psi = \dfrac{\sin a}{\sin \zeta_\psi} \\[2ex]
\cos b = \dfrac{\tan a}{\tan \zeta_\psi} & \cos \psi = \dfrac{\tan \zeta}{\tan \zeta_\psi} \\[2ex]
\tan b = \dfrac{\tan \zeta}{\sin a} & \tan \psi = \dfrac{\tan a}{\sin \zeta} \\[2ex]
\sin b = \dfrac{\cos \psi}{\cos a} & \sin \psi = \dfrac{\cos b}{\cos \zeta} \\[2ex]
\cos \zeta_\psi = \cos \zeta \cos a & \cos \zeta_\psi = \cot b \cot \psi
\end{array}\right\} \quad (7)$$

The heading and roll being known, the second equation of the second line of this group gives the heading of the ship by the tilted card, and vice versa if the magnetic axis still remains in the vertical plane of the magnetic meridian. But as the card is tilted, components of the Earth's magnetic field arise that force its magnetic axis away from the plane of the magnetic meridian.

Let the point I in the stereographic projection of Figure 4 represent the direction of the Earth's magnetic field; that is, the intersection of the north-seeking end of the dip needle prolonged to meet the sphere. The magnetic inclination I is measured by the arc NI and $(NI + NN_\psi) = (I + a)$ is the angle between the direction of the Earth's magnetic field and the intersection of the vertical plane of the magnetic meridian $N_\psi OS$ with the tilted plane $BP_\psi AQ_\psi$. The components of the total intensity of the Earth's field F, along this intersection and perpendicular to it in the vertical plane of the magnetic meridian (see Fig. 5) will therefore be:

$$F \cos (I + a) \quad (8)$$
$$F \sin (I + a) \quad (9)$$

The component perpendicular to the intersection given by (9) may be resolved into the components

$$F \sin (I + a) \sin b \quad (10)$$
$$F \sin (I + a) \cos b \quad (11)$$

the first of which being perpendicular to the inclined plane can have no directive effect on the compass-card, which is assumed to move freely only in this plane. The other acts at right-angles to the intersection and, combined with the component along the

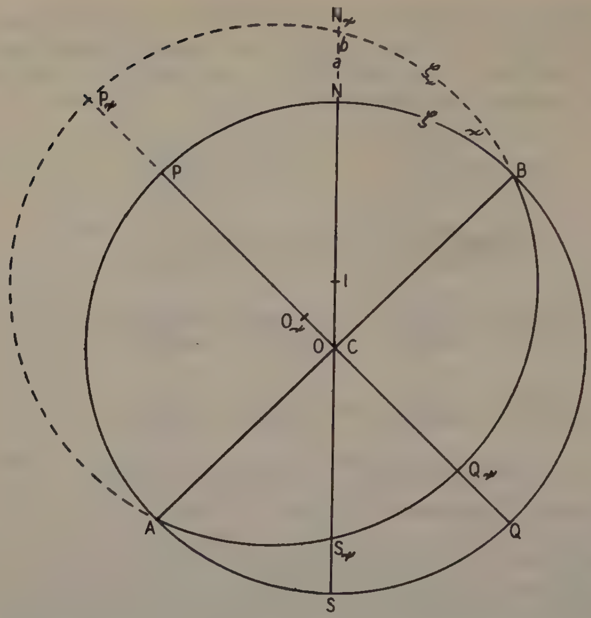

FIG. 4—Stereographic projection upon plane of horizon looking towards nadir

intersection (8), gives the single component, H_ψ of the Earth's field lying in the plane of apparent level, that is, the plane of the tilted card.

The relative magnitudes of these components for tilt to starboard and for tilt to port are more obvious in the perspective of the planes drawn to scale as in Figure 6. The aspect of the vertical plane of the magnetic meridian, V, and the horizontal plane, H, is identical in both views. The Earth's magnetic field represented by the heavy partly dotted line CI is also the same in length and direction in both views, being directed downward with a dip of 45°. The axis of tilting lies in the horizontal plane, and is 45° eastward from north, so that the nearest point of the horizontal plane in both views is northeast from the center. The plane of apparent level, that is, the plane of the tilted card is represented by shaded planes in both views, and the angle of tilt is +33°, or downward towards southeast in the upper view, and −33° or downward towards northwest in the lower view. The components in the V-plane along the intersection, $F \cos (I+a)$, and perpendicular to it, $F \sin (I+a)$, are represented by CJ and IJ respectively. The component $F \sin (I+a) \cos b$, which is the effective component in turning the magnetic axis of the card from the plane of the magnetic meridian V is represented by JK. The difference in the length of JK as shown in the two views is quite obvious. The

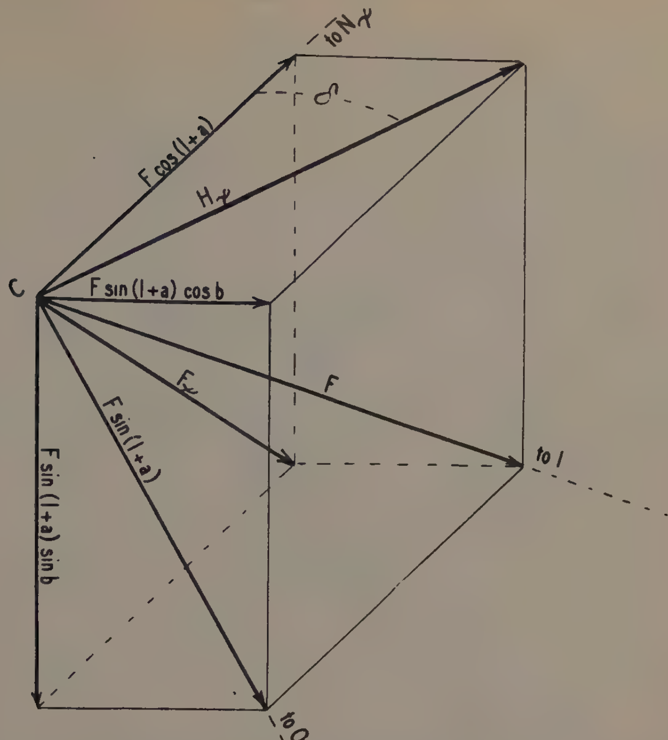

FIG. 5—Vectors representing the Earth's magnetic field and its components in the tilted planes

other components are not drawn so as not to detract from the clarity of the views, but they may be readily visualized.

A line from C to K would represent the single component of the resolved field in the tilted plane.

The angle δ in the tilted plane between the component H_ψ and the component $F \cos (I+a)$ (see Fig. 5), which is in the plane of the magnetic meridian is the deviation of the resolved field due to tilting, and is given by:

$$\tan \delta = \frac{F \sin (I+a) \cos b}{F \cos (I+a)} = \tan(I+a) \cos b$$

$$= \frac{\tan I + \sin \zeta \tan \psi}{1 - \tan I \sin \zeta \tan \psi} \cos \zeta \sin \psi \qquad (12)$$

These expressions are equivalent to Thomson's

$$\tan \phi = \tan (\zeta_\psi - \delta_\psi) = \cos \psi \tan \zeta + \tan I \sin \zeta \sec \psi$$

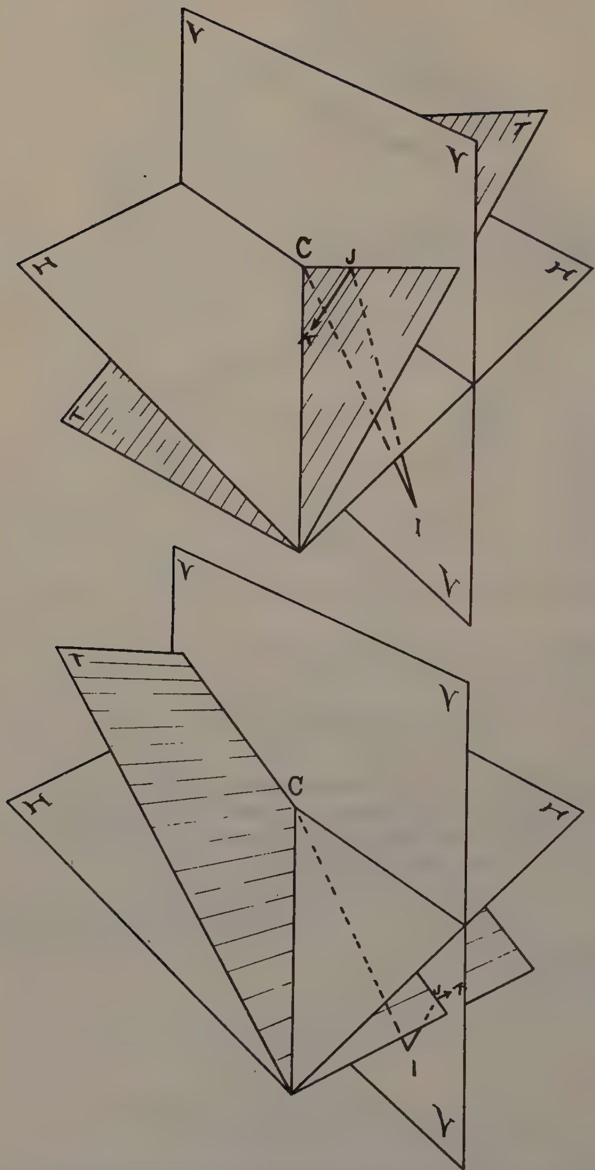

FIG. 6—Perspective views of vertical, horizontal, and tilted planes

and Starling's

$$\tan\,(\zeta_\psi-\delta_\psi)=\cos\psi\,\tan\zeta-\tan I\,\sin\psi\,\sec\zeta$$

if ψ is taken in the same sense in the three cases. Table 3 gives the values of δ on an intercardinal heading when the magnetic inclination is $+71°$ for various values of the angle of tilt. These values of δ are the maximum oscillations that an undamped card of negligible mass of extremely short period, and oscillating only in the tilted plane, would experience for the tabulated values of tilt. The table shows large differences between values for opposite tilts of the same amplitude. If the extreme oscillations of such a card were recorded while taking some bearing, the error of the mean bearing would be the mean as given in the lowest line of the table. The ordinary ship's compass-card has a period too long to follow the changing direction of the resolved field in the tilting plane of apparent level which oscillates from one extreme to the other in one-half the period of the swing or the vessel. There is also the

E 3—*Examples of the magnitude expressed in degrees and the sign of* δ_ψ *for various values of* ψ
($I=+71°$, $\zeta=+45°$)

+5°	−5°	+9°	−9°	+10°	−10°	+11°	−11°	+14°	−14°	+15°	−15°	+16°	−16°
+12.6	−8.5	+26.2	−13.1	+30.2	−14.1	+34.3	−14.9	+47.1	−17.1	+51.5	−17.8	+55.8	−18.3
+2.0		+6.6		+8.0		+9.7		+15.0		+16.8		+18.8	

condition, ignored in the foregoing, that the plane of the card may not coincide exactly and continuously with the plane of apparent level. The card and its magnetic axis are made presumably horizontal by the manufacturer by adjusting the center of gravity vertically under the point of the pivot and the center of buoyancy (in liquid compasses) in the same vertical. Even if the adjustment were perfectly made for one locality and a condition of rest, it would not remain perfect in other localities or for conditions of motion. It might be noted here that while Bidlingmaier's theory of dynamic deviations assumes the magnetic axis to be always horizontal, this theory of tilting deviations assumes it to be always in the plane of apparent level, neither of which assumptions is strictly true.

No method of actually measuring such changes in adjustment in the ordinary navigational compass is suggested at the present time. But it is known from standardizing observations made with the marine collimator of the Department of Terrestrial Magnetism that the tilt of this card varies about 1°.15 between a station made in Bronx Park, New York, and one made at Cape Town.[8]

[8] *Res. Dep. Terr. Mag.*, v. 3 (189).

TABLE 4—*Values of the deviation in declination in the tilted plane* ($I = 71° 15'$, $\psi = \pm 10°$)

ζ	0°	45°	90°	135°	180°	225°	270°	315°
	°	°		°	°	°		°
$\delta+\psi$	+27.1	+30.8	0	−30.8	−27.1	−14.2	0	+14.2
$\delta-\psi$	−27.1	−14.2	0	+14.2	+27.1	+30.8	0	−30.8
Means	0	+ 8.3	0	− 8.3	0	+ 8.3	0	− 8.3

TABLE 5—*Compass-deviations*[a] *and amplitudes of compass-oscillations observed on experimental wooden swing February and March, 1929*

Axle Magnetic course, ζ	N—S 0° – 180°		NE—SW 45° – 225°		E—W 90° – 270°		SE—NW 135° – 315°		Period[b]
One-half arc, degrees Radius, meters	10 2.52	19.5 1.32	10 2.52	19.5 1.32	10 2.52	19.5 1.32	10 2.52	19.5 1.32	
	°	°	°	°	°	°	°	°	s
Ritchie 29499[c]									42
Deviation	−0.1	−0.1	+2.3	+1.1	+0.3	0.0	−2.7	−1.5	
Amplitude oscillation	1 9	2.6	1.8	2.5	1.1	1.4	0.7	0.5	
Thomson 7784[d]									35.5
Deviation	−0.8	−1.4	−1.2	−1.5	+0.6	+0.5	+1.3	+1.4	
Amplitude oscillation	0.6	1.5	0.1	1.2	0.0	1.0	0.5	0.1	
Thomson 14148[d]									30
Deviation	−0.6	.....[f]	−1.0	−1.0	+0.4	+0.1	+1.0	+1.3	
Amplitude oscillation	0.6	.....[f]	0.0	1.4	0.3	1.1	0.7	0.0	
Thomson 13845[d]									22.5
Deviation	−0.4	−0.7	+0.3	−0.1	+0.2	0.0	−0.1	−0.8	
Amplitude oscillation	1.0	1.8	0.6	1.3	0.4	0.6	1.7	0.5	
Boat W. C., D-186[c]									16.0
Deviation	0	0	−1	−1	0	0	+1	+1	
Amplitude oscillation	2	2	2	2	0	0	2	2	
Aircraft[c, e, g]									13
Deviation	0	0	0	−1	0	0	0	0	
Amplitude oscillation	8	8	5	5	0	0	5	5	
Pocket 15[d, e]									2
Deviation	−1	−5	−8	−2	0	0	+2	+10	
Amplitude oscillation	90	100	70	80	0	5	66	84	

[a] Plus to east, minus to west. [b] Approximate for $H = 0.186$ *c. g. s.* [c] Liquid compass. [d] Dry compass. [e] Not mounted in gimbals. [f] Too unsteady for observations. [g] Type MS II, No. 28-27.

Table 4 shows the oscillations and their means as computed for one amplitude of swing, $\pm 10°$, for the cardinal and intercardinal headings and for a value of magnetic dip $+71° 15'$. Table 5 gives the oscillations and deviations actually observed for the same magnetic dip and condition of motion with five different compasses. The Thomson compass has three different cards as follows: Nos. 7784, 14148, and 13845, with 6, 8, and 14 magnets each, of total weights (card and magnets) 11.2, 13.5, and 17.6 grams, respectively. These cards are divided, as usual, into quadrants subdivided into single degree divisions. Boat-compass Wilcox-Crittenden D-186 is graduated into divisions of two degrees from 0° to 358°. The air-craft compass has divisions of five degrees, and the pocket-compass is rather crudely divided into 10° divisions, not floating or suspended, as in all the other compasses, but marked on the bottom of the box.

The method of the experiments differed from those of Table 1 in that readings were made at the extremes of consecutive oscillations as soon as the swing was in motion, and the means of the second series of 13 readings were used. Readings were made through a telescope, and were probably more accurate than those of the earlier experiments, on account of better visibility, but on the other hand very much less time was given to each compass.

Expressions for the other magnetic elements in the tilted planes may be written from an inspection of Figure 5. The single component of the Earth's field in the plane of apparent level is

$$H_\psi = F\sqrt{\cos^2 (I+a)+\sin^2 (I+a) \cos^2 b} \qquad (13)$$

The single component in the plane perpendicular to the plane of apparent level, that is, the plane of apparent magnetic dip is

$$F_\psi = F\sqrt{\cos^2 (I+a)+\sin^2 (I+a) \sin^2 b} \qquad (14)$$

The direction of this component referred to the component $F \cos (I+a)$ is the apparent magnetic dip given by

$$\tan I_\psi = \frac{F \sin (I+a) \sin b}{F \cos (I+a)} = \tan (I+a) \sin b \qquad (15)$$

TABLE 6—*Values of the total component H_ψ of the Earth's field in the tilted plane* ($F=0.5693$ *c. g. s.*, $I=+71° 15'$, $\psi=\pm 10°$)

ζ	0°	45°	90°	135°	180°	225°	270°	315°
H_{+10}	.2055	.1337	.0867	.1337	.2055	.2561	.2738	.2561
H_{-10}	.2055	.2561	.2738	.2561	.2055	.1337	.0867	.1337
Means	.2055	.1949	.1802	.1949	.2055	.1949	.1802	.1949
H	.1830	.1830	.1830	.1830	.1830	.1830	.1830	.1830
Diff.	+.0225	+.0119	−.0028	+.0119	+.0225	+.0119	−.0028	+.0119

TABLE 7—*Values of the apparent dip I_ψ in the tilted vertical plane* ($I=+71°\ 15'$, $\psi=\pm 10°$)

ζ	0°	45°	90°	135°	180°	225°	270°	315°
	°	°	°	°	°	°	°	°
$I+10$	70.98	78.26	81.25	78.26	70.98	63.98	61.25	63.98
$I-10$	70.98	63.98	61.25	63.98	70.98	78.26	81.25	78.26
Means	70.98	71.12	71.25	71.12	70.98	71.12	71.25	71.12
I	71.25	71.25	71.25	71.25	71.25	71.25	71.25	71.25
Diff.	−.27	−.13	.00	−.13	−.27	−.13	.00	−.13

The sines and cosines of $(I+a)$ may be expanded and the sines and cosines of a and b may be replaced by functions of ζ and ψ as given or deduced from equations (7). Tables 6 and 7 give values of H_ψ and I_ψ and their deviations from H and I respectively for $I=71°$ $15'$ and angles of tilt $+10°$ and $-10°$.

The deviations in horizontal intensity and magnetic inclination will be the subject of a future paper. But an investigation of the effect of mass, magnetic moment, and damping on the tilting deviations of a compass requires an expression for the uniform oscillating field in the tilting plane. Such an expression is given by the equation (13) for $H\psi$, which, when substituted in the equation of motion of a magnet oscillating in a uniform field about its center of mass and subject to damping proportional to its velocity, gives

$$\frac{d^2\theta}{dt^2}+\frac{\mu}{\mathrm{I}}\frac{d\theta}{dt}+\frac{mF}{\mathrm{I}}\sin(\delta-\theta)\sqrt{1-\sin^2 b\sin^2(\imath+a)}=0 \quad (16)$$

in which θ is the angle at any instant t between the axis of card and the intersection of the tilted plane with the vertical plane of the magnetic meridian and μ is the coefficient of damping, **I** the moment of inertia, and m the magnetic moment of the magnet. The angle of tilt at any moment t is

$$\psi=\Psi\sin nt \text{ or } \psi=\pm\Psi\cos nt \quad (17)$$

according to the initial conditions, where ψ is the maximum amplitude of the oscillations of the tilting plane and

$$n=2\pi/\mathrm{T} \quad (18)$$

in which T is the period of the tilting plane. Expanding $\sin(\delta-\theta)$ and substituting the identities.

$$\sin\delta=\frac{\sin(I+a)\cos b}{\sqrt{1-\sin^2 b\sin^2(I+a)}} \qquad \cos\delta=\frac{\cos(I+a)}{\sqrt{1-\sin^2 b\sin^2(I+a)}} \quad (19)$$

which are evident from Figure 5, equation (16) becomes

$$\frac{d^2\theta}{dt^2}+\frac{\mu}{I}\frac{d\theta}{dt}+\frac{mF}{I}\ \{+[\cos I \sec \zeta \cos (\Psi \sin nt)-\sin I \tan \zeta \sin (\Psi \sin nt)] \sin \theta-[\cos I \sin \zeta \sec^2 (\Psi \sin nt)+(1/2) (\sin I \sin 2 (\Psi \sin nt)] \cos \theta\}\ \{1/[\cos^2 (\Psi \sin nt + \tan^2\zeta)]^{1/2}\}=0 \quad (20)$$

Equation (20) is susceptible of considerable simplification if numerical values are given to the known quantities. Experiment indicates that the angle θ for a ship's compass is usually not more than 5° for any angle of tilt up to 10° except at the instant of beginning, and then only when the initial condition is $\psi=\pm\Psi$. Some experiments have been made to which this equation is applicable, but final results are not yet available. It is, however, quite evident from curves computed from equation (20) by C. R. Duvall, after the substitution of assumed numerical values, that a mean value of θ for an interval of time, beginning half a minute after initial conditions in order for the compass to settle down, will be a small fraction of the mean deviations given in Tables 3 and 4 for the same angle of tilt. It is not evident, however, at least from casual inspection, that negative values of θ on NE-SW and positive values on SE-NW as given by experiments, Tables 1 and 5, will follow from equation (20) through the substitution of any numerical values plausible for the damping factor, the moment of inertia, and the magnetic moment.

In concluding, it might be emphasized that a condition or conditions exist that have not as yet been taken into consideration, probably such as stated under condition (*b*) page 100, and elaborated in more detail on page 111, which result in masking the combined effect of dynamic and tilting deviations.

The experiments, at times quite tedious, were all made with the patient and interested assistance of various members of the staff, especially H. F. Johnston, J. W. Green, and G. R. Wait. C. R. Duvall has verified many of the numerical calculations, in addition to computing the curves of the differential equation.

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REVIEWS AND ABSTRACTS

(See also pages 122 and 161)

RÖSSIGER, M.: *Die Messung der Horizontal- und der Vertikalintensität des erdmagnetischen Feldes mit dem Magnetron.* Zs. Instrumentenk., Berlin, Jahrg. 49, Heft 3, 1929 (105-113).

Hull's magnetron is used as an indicating instrument for the measurement of the horizontal and vertical components of the Earth's magnetic field. It is a vacuum-tube somewhat similar to the tubes commonly used in radio reception and has two electrodes one of which is a straight filament heated by a current and serving as a source of electrons. The other electrode is a cylindrical plate, the axis of which is the filament. The filament is the cathode and the plate is the anode of the tube. The current between the filament and the plate can be practically stopped by applying a magnetic field parallel to the filament. If the applied magnetic field is below a certain critical value it has little influence on the current. At the critical value the current decreases very rapidly and above it the current is zero. In the transition region the instrument is a sensitive indicator of changes in the magnetic field. A change of 20γ corresponds to an easily measurable current change of 2×10^{-7} ampere.

The magnetron is placed inside a coil L coaxial with the filament. A current is maintained through L so as to give an axial field close to the critical value. The magnetron and L form the indicator. This indicator is mounted rigidly inside a pair of Helmholtz coils and the whole system may be turned about a horizontal and vertical axis.

In order to measure the horizontal intensity the filament is brought into a horizontal position. The apparatus is next rotated about a vertical axis and the plate-current is read; its maximum and minimum occur when the filament lies in the magnetic meridian. Having fixed the filament in the meridian plane the plate-current is read. The apparatus is swung through 180 degrees about a horizontal axis and the plate-current is brought back to its old value by sending a current through the Helmholtz coils. The compensating field of the Helmholtz coils is then twice the horizontal intensity. The vertical component is measured similarly.

The chief practical problem in the method has been the unsteadiness in the operation of the magnetron. This has been traced to two main causes, namely, bad vacuum and fluctuations in the filament current. Thorough baking and pumping have solved the first and an ingenious compensation-scheme has solved the second. The compensation for changes in filament current is brought about by making the coil L of two parts. One part L_1 is fed by a separate storage-battery. The other L_2 is connected in series with the filament. A fluctuation in filament-current changes its emission and produces the troublesome fluctuation in plate-current. However, the same fluctuation produces a change in the magnetic field, which, when a proper number of turns for L_2 is chosen, produces an equal and opposite fluctuation in plate-current.

The accuracy of the method at present is 40γ. The total weight of the apparatus is 40 kg of which 25 kg is due to storage-batteries. It has been compared with the magnetometer at Potsdam with satisfactory results. The advantages of the method are found in the lack of inertia in the response of the magnetron to the magnetic field, absence of parts requiring dynamical correction, as, for example, on board ship, and the possibility of using the same apparatus for the horizontal and vertical intensity. G. BREIT

PRELIMINARY RESULTS OF OCEAN MAGNETIC OBSERVATIONS ON THE *CARNEGIE* FROM CALLAO TO SAMOA, FEBRUARY TO MARCH, 1929[1]

By J. P. Ault, *Commanding the Carnegie*

TABLE 1—*Preliminary Magnetic Results on Cruise VII of Carnegie, Pacific Ocean February to March, 1929* (*Observers:* J. P. Ault, O. W. Torreson, F. M. Soule, W. E. Scott, L. A. Jones, and J. H. Paul)

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1929	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Feb. 6[c]	12 00 S	281 26	8.7 E	...	...	+0.1	0.0	−0.1	...	...	...	...	...	...
7	10 34 S	280 21	9.1 E	...	...	+0.6	+0.5	+0.4	...	...	...	...	...	...
7	10 19 S	280 09	...	2.5 N	.308	...	...	...	+1.3	+0.9	+1.0	+18	+3	+14
7	10 05 S	279 30	9.1 E	...	...	+0.5	+0.2	+0.2	...	...	...	...	...	...
8	10 00 S	278 04	9.3 E	...	...	+0.3	0.0	+0.1	...	...	...	...	...	...
8	10 00 S	277 21	9.8 E	...	...	+0.6	+0.3	+0.3	...	...	...	...	...	...
9	10 15 S	276 04	9.7 E	...	...	+0.2	−0.2	−0.1	...	...	...	...	...	...
9	10 21 S	275 54	...	0.0	.311	...	...	...	+0.9	+0.4	+1.3	+15	+1	+12
9	10 31 S	275 35	10.0 E	...	...	+0.4	−0.1	0.0	...	...	...	...	...	...
11	10 35 S	274 17	10.5 E	...	...	+0.5	+0.1	+0.4	...	...	...	...	...	...
11	10 40 S	273 58	...	1.6 S	.311	...	...	...	+0.3	−0.1	+1.2	+13	0	+9
11	10 42 S	273 43	10.6 E	...	...	+0.5	+0.1	+0.4	...	...	...	...	...	...
12	10 58 S	272 49	10.6 E	...	...	+0.3	−0.1	+0.1	...	...	...	...	...	...
12	11 21 S	272 01	11.0 E	...	...	+0.5	+0.2	+0.4	...	...	...	...	...	...
13	12 14 S	270 51	11.3 E	...	...	+0.5	+0.2	+0.4	...	...	...	...	...	...
13	12 25 S	270 36	...	6.6 S	.310	...	...	...	+0.3	−0.7	+0.2	+12	0	+7
13	12 57 S	269 41	11.4 E	...	...	+0.6	0.0	+0.4	...	...	...	...	...	...
14	14 06 S	268 09	11.8 E	...	...	+0.2	+0.2	+0.3	...	...	...	...	...	...
14	14 46 S	267 11	11.9 E	...	...	+0.1	+0.1	+0.2	...	...	...	...	...	...
15	15 54 S	265 29	12.4 E	...	...	+0.2	+0.5	+0.3	...	...	...	...	...	...
15	15 53 S	265 22	...	15.9 S	.306	...	...	...	−0.7	−1.0	−0.8	+9	−2	+4
15	15 42 S	264 31	12.4 E	...	...	+0.2	+0.4	+0.3	...	...	...	...	...	...
16	15 20 S	262 46	12.0 E	...	...	0.0	+0.1	+0.1	...	...	...	...	...	...
16	15 06 S	261 38	12.2 E	...	...	+0.3	+0.5	+0.4	...	...	...	...	...	...
17	14 38 S	259 47	11.7 E	...	...	+0.1	+0.1	+0.1	...	...	...	...	...	...
17	14 44 S	259 33	...	16.1 S	.308	...	...	...	−0.2	0.0	−0.9	+4	−6	+1
17	14 40 S	258 26	11.6 E	...	...	−0.1	+0.1	+0.1	...	...	...	...	...	...
18	14 20 S	256 51	11.6 E	...	...	+0.1	+0.3	+0.2	...	...	...	...	...	...
18	14 12 S	256 09	11.2 E	...	...	−0.2	−0.1	0.0	...	...	...	...	...	...
19	13 45 S	254 45	11.3 E	...	...	+0.1	+0.1	+0.2	...	...	...	...	...	...
19	13 31 S	253 53	...	15.8 S	.313	...	...	...	−0.3	−0.4	−0.7	+3	−5	+1
19	13 28 S	253 30	11.2 E	...	...	+0.1	+0.2	+0.3	...	...	...	...	...	...
20	13 04 S	252 09	11.1 E	...	...	+0.1	−0.1	+0.3	...	...	...	...	...	...

[a]Charts used for comparison: U. S. Hydrographic Office charts 1700, 1701, and 2406 for 1925; British Admiralty charts 777 for 1927, 3598 and 3603 for 1922; Reichs-Marine-Amt. charts Tit. XIV, 2, 2a, and 2b for 1920. All chart-values have been corrected to 1929.2 on account of secular-change rate indicated by the respective charts. The chart-differences are obtained by subtracting the chart-values from those determined on the *Carnegie*, east declination, north inclination, and horizontal intensity being reckoned as positive and west declination and south inclination as negative.

[b]Expressed in units of third decimal C. G. S.

[c]The *Carnegie* was at Callao, Peru, during January 14 to February 5, 1929.

For previous values obtained on Cruise VII, see *Terr. Mag.*, v. 33, pp. 121-128, 189-194, and v. 34, pp. 23-31.

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
				I	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S
1929	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Feb. 20	12 53 S	251 22	10.7 E	......	......	−0.2	−0.2	0.0	.....	.....	.....	.....	.....	.....
21	12 36 S	250 25	10.3 E	......	......	−0.5	−0.5	−0.3	.....	.....	.....	.....	.....	.....
21	12 32 S	250 08	......	15.0 S	.318	.....	.....	.....	−0.1	−0.5	−0.4	+4	−3	+3
21	12 34 S	249 22	10.6 E	......	......	−0.2	−0.3	+0.2	.....	.....	.....	.....	.....	.....
22	12 35 S	247 57	10.6 E	......	......	−0.2	−0.2	+0.1	.....	.....	.....	.....	.....	.....
22	12 35 S	247 09	10.4 E	......	......	−0.3	−0.3	−0.1	.....	.....	.....	.....	.....	.....
23	12 33 S	245 33	10.4 E	......	......	−0.3	−0.3	−0.1	.....	.....	.....	.....	.....	.....
23	12 32 S	245 11	......	16.6 S	.320	.....	.....	.....	−0.4	−0.5	−0.7	+3	−2	+4
23	12 32 S	244 14	10.2 E	......	......	−0.4	−0.4	−0.2	.....	.....	.....	.....	.....	.....
24	12 38 S	242 46	9.7 E	......	......	−0.9	−0.8	−0.6	.....	.....	.....	.....	.....	.....
24	12 44 S	241 58	9.9 E	......	......	−0.7	−0.6	−0.4	.....	.....	.....	.....	.....	.....
25	12 45 S	240 59	10.2 E	......	......	−0.4	−0.2	−0.1	.....	.....	.....	.....	.....	.....
25	12 45 S	240 46	......	17.2 S	.320	.....	.....	.....	+0.3	+0.2	+0.4	0	−4	+2
25	13 02 S	240 11	10.1 E	......	......	−0.5	−0.4	−0.2	.....	.....	.....	.....	.....	.....
26	13 03 S	238 59	10.0 E	......	......	−0.5	−0.5	−0.3	.....	.....	.....	.....	.....	.....
26	13 05 S	238 06	10.0 E	......	......	−0.5	−0.4	−0.3	.....	.....	.....	.....	.....	.....
27	13 06 S	236 32	10.0 E	......	......	−0.5	−0.4	−0.3	.....	.....	.....	.....	.....	.....
27	13 37 S	235 37	......	20.1 S	.323	.....	.....	.....	+0.1	−0.5	+0.3	+2	−3	+2
27	13 48 S	235 21	9.9 E	......	......	−0.6	−0.5	−0.5	.....	.....	.....	.....	.....	.....
28	14 44 S	234 06	10.4 E	......	......	−0.3	−0.1	−0.2	.....	.....	.....	.....	.....	.....
28	15 17 S	233 23	10.7 E	......	......	−0.1	+0.1	0.0	.....	.....	.....	.....	.....	.....
Mar. 1	16 11 S	232 21	10.5 E	......	......	−0.4	−0.4	−0.4	.....	.....	.....	.....	.....	.....
1	16 21 S	232 08	......	25.1 S	.323	.....	.....	.....	+0.5	+0.8	+0.1	+5	+1	+5
1	16 55 S	231 33	10.7 E	......	......	−0.3	−0.2	−0.3	.....	.....	.....	.....	.....	.....
2	16 59 S	230 26	10.7 E	......	......	−0.3	−0.3	−0.3	.....	.....	.....	.....	.....	.....
2	17 01 S	229 46	10.8 E	......	......	−0.2	−0.2	−0.2	.....	.....	.....	.....	.....	.....
3	17 08 S	228 41	10.4 E	......	......	−0.7	−0.6	−0.7	.....	.....	.....	.....	.....	.....
3	17 09 S	228 28	......	26.9 S	.324	.....	.....	.....	+1.0	+0.7	+0.3	+6	+1	+6
3	17 08 S	227 51	10.9 E	......	......	−0.2	−0.1	−0.2	.....	.....	.....	.....	.....	.....
4	17 10 S	226 48	10.8 E	......	......	−0.3	−0.2	−0.3	.....	.....	.....	.....	.....	.....
4	17 09 S	226 13	10.9 E	......	......	−0.2	−0.1	−0.2	.....	.....	.....	.....	.....	.....
5	17 07 S	225 06	10.9 E	......	......	−0.1	0.0	−0.1	.....	.....	.....	.....	.....	.....
5	17 06 S	224 52	......	27.7 S	.325	.....	.....	.....	+0.8	+0.3	+0.4	+5	0	+5
5	17 04 S	224 17	10.7 E	......	......	−0.3	−0.2	−0.2	.....	.....	.....	.....	.....	.....
6	17 11 S	223 27	10.8 E	......	......	−0.2	−0.1	−0.1	.....	.....	.....	.....	.....	.....
7	17 16 S	221 43	10.5 E	......	......	−0.5	−0.4	−0.4	.....	.....	.....	.....	.....	.....
7	17 21 S	221 22	......	29.0 S	.324	.....	.....	.....	+0.2	−0.1	+0.7	+1	−3	+1
7	17 32 S	220 33	10.9 E	......	......	−0.2	0.0	−0.1	.....	.....	.....	.....	.....	.....
8	17 38 S	219 17	10.8 E	......	......	−0.2	−0.1	−0.2	.....	.....	.....	.....	.....	.....
9	17 36 S	218 12	10.9 E	......	......	−0.1	0.0	−0.1	.....	.....	.....	.....	.....	.....
10	18 05 S	216 27	11.0 E	......	......	−0.1	−0.1	−0.1	.....	.....	.....	.....	.....	.....
10	18 04 S	216 12	......	30.8 S	.331	.....	.....	.....	+0.2	+0.5	+0.5	+8	+2	+6
11	18 04 S	214 32	11.1 E	......	......	0.0	0.0	0.0	.....	.....	.....	.....	.....	.....
11	18 14 S	213 42	11.4 E	......	......	+0.3	+0.3	+0.3	.....	.....	.....	.....	.....	.....
12	17 58 S	212 34	11.2 E	......	......	+0.1	+0.1	+0.1	.....	.....	.....	.....	.....	.....
12	17 54 S	212 17	......	31.4 S	.330	.....	.....	.....	−0.4	0.0	−0.2	+3	−2	+2
12	17 44 S	211 27	10.5 E	......	......	−0.5	−0.5	−0.4	.....	.....	.....	.....	.....	.....

Notes on Trip From Callao, Peru, to Papeete, Tahiti, February 5 to March 13, 1929

The *Carnegie* sailed from Callao Bay under her own power at $15^h\ 20^m$, February 5, using the engine until the next morning on account of calm. Here the regular observational program began with an ocean-station, and continued without interruption, except for a stop of one day at Amanu Island, until arrival at Papeete, March 13. The weather was excellent, with no storms and good breezes. The engine was not required except when the trade-wind was interrupted among the Tuamotu Islands and during the squally weather approaching Tahiti.

The magnetic work was carried out as usual. Experiments to determine horizontal intensity with the earth inductor were continued. Different coils were used, and some encouragement was given for ultimate success by the improved agreement of results with those of deflector 5. Further experiments must be made before report is made.

The usual atmospheric-electric program was made. Twenty-three complete potential-gradient electrograms were obtained and three and one-half diurnal-runs were made.

The oceanographic work was entirely successful. One of the new bottom-samplers made at Callao gave some trouble by failure to close, but the difficulty was overcome. The lead weight was counter-sunk to allow it to fit down over the clamping spring, thus bringing the center of gravity of the falling snapper nearer to the jaws, to insure that they strike the bottom in an upright position. Only once was there a failure to secure a sample when attempted. At one station no attempt was made. The samples themselves have shown considerable variation, the colors ranging from white to gray, light brown, blue-green, coffee-colored, chocolate, and black mud, sand, ooze, and lava. One of the new Sigsbee reversing frames was modified to hold two of the Richter and Wiese thermometers, and was sent down on the drift-wire, 20 meters above the snapper, at each ocean-station after February 27. Thus the bottom temperature and the depth were secured. Experiment showed that it requires 25 meters of vertical haul to reverse the thermometers.

Up to February 28 five minutes had been allowed to elapse after the bottle-series had reached the proper depth before releasing the messenger for reversal. Due to a slight discrepancy between the two temperatures at the overlapping depth, it was decided to allow ten minutes to elapse hereafter before reversal begins. The temperatures undoubtedly were accurate for the protected thermometers, but there might be some lag in the unprotected tube with its load of surface-water to cool off and the pressure-effect to register. An improvement in the agreement between the overlapping temperatures has since been noticed.

The Pettersson plankton-pump fails to operate occasionally

and must be sent down again. It was completely overhauled on February 19. Considerable patience is required to operate it. The results promise an extremely valuable addition to the qualitative as well as the quantitative data on plankton-life and distribution.

During some of the ocean-stations when the vessel was rolling and pitching more than usual, the silk tow-nets were torn by the quick jerking of the ship's motion. Use was then made of the airplane rubber rope, the inboard end of the tow-line being secured to a 20-foot length of rubber rope to ease the strain on the tow-line when the vessel surges. The rubber rope would increase its length to 28 feet at times. The nets have not torn since using this device, but the seas have been much smoother.

The balloon work has been unusually successful, due to clear skies and moderately smooth motion. Some thought has been given to improvements to increase the efficiency of the theodolite when used in stormy latitudes. The use of the sextant for measuring altitudes increases the time of following the balloon, especially on rough days. It permits the observer at the theodolite to keep one hand on the counter-weight below to assist in keeping the instrument level, while the other hand operates the horizontal-circle screw. If the balloon is lost to the theodolite, the sextant gives its altitude and approximate bearing by the direction of the sextant-pointing.

In view of the length of time required to hold up a sextant and of the weight of the new balloon-sextant, it became necessary to devise some method for supporting the instrument. One of the deck-chairs was provided with arms and two upright pieces supporting an overhead bar. A fine spring was suspended from this bar, and the sextant is now used hanging from this spring. The entire weight is supported at the height of the observer's eye, and the freedom of motion is in no wise restricted.

The trade-wind was more southerly than expected soon after leaving the Peruvian coast, so that we could not follow exactly the route as planned. Later the portion of the 1916 track from 112° west to 17° south was followed exactly. Here it was decided to head west through the Tuamotu Islands, direct for Tahiti instead of continuing south around this group. This would increase the value of the oceanographic section, almost due west from the coast of Peru to Tahiti, give additional data as to depths in the Tuamotu Group, and avoid near approach to the Rapa Island portion of the present cruise to be made in 1931. Tatakoto Island was sighted early on March 7, and on March 8 the vessel was hove to off Amanu Island while the scientific staff made a visit ashore. About 270 people live on Amanu, chiefly engaged in gathering copra. They appear healthy, happy, and prosperous, and of a very high class of South Sea Islander. There are no white people on the island. They gave us a large number of cocoanuts, and when we returned to the vessel in the afternoon the Chief and a boatload of men and women accompanied us to see the ship.

The oscillator has given excellent service since repairs at Callao. On February 8 the depth-finder was moved from the radio-room to the control-room, to decrease the crowded condition of the radio-room and to provide for an enlarged program of depth-finding without disturbing the radio operator at all times of day and night. The change has worked out well and has increased the comfort and efficiency all around. On February 19 the depth-finder was completely overhauled and spare parts substituted for worn ones.

On February 16, at 17^h 19^m ship's time, latitude 15°.1 south, longitude 98°.3 west, the depth shoaled rapidly from 5380 meters to 3403 meters, after which it again deepened to 4530 at 17^h 29^m, when again there was a gradual decrease to 4080 meters. The deep thus revealed was named "Bauer Deep," in honor of Director Louis A. Bauer. Throughout the cruise from Callao to Papeete the bottom has been very irregular, as evidenced also by the many echoes, as many as six surfaces being indicated.

While passing through the Tuamotu Group, many soundings were taken in order to develop the bottom-contour in this region. Thirteen soundings were taken on March 7, eleven on March 8, and nine on March 9, giving a valuable contribution to our knowledge of the formation in the vicinity of both Tatakoto and Amanu islands. A new ridge, 2,000 meters above the general contour was discovered at 17° 40′ south and 141° 37′ west, between Amanu and Hikueru islands A few miles later at the ocean-station, we had hard bottom, with a few fragments of black lava, with no trace of ooze, showing possibility of fairly recent volcanic origin.

Unusually good radio conditions were found soon after leaving Callao, and frequent schedules were arranged with amateurs in various parts of the United States, in Honolulu, in Jamaica, and in Panama. Later it became necessary to communicate with the American Radio Relay League station WIMK at Hartford, Connecticut, which has been so continuously helpful on this cruise, through two relays, namely, Yosemite, California (W6CIS), and Fort Madison, Iowa (W9BCA). Thus it was possible to keep the office fully informed of the daily progress and of urgent needs.

During the passage from Callao to Papeete observations were obtained as follows: 63 declination-stations, 17 inclination and horizontal-intensity stations; 3½ eye-reading, 24-hour atmospheric electric runs; 23 complete 24-hour potential-gradient electrograms; 17 ocean-stations, including tow-nets and plankton-pump; 206 sonic depths; 35 balloon-flights; 9 evaporation-series; and one biological station. This summary of work done speaks for the smoothness and efficiency with which the members of the party, individually and as a whole, are carrying out the work of the expedition.

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Washington, D. C.

REVIEWS AND ABSTRACTS

(See also pages 116 and 161)

Heiland, C. A.: *Geophysical methods of prospecting. Principles and recent successes.* Q. Colo. School Mines, Golden, Colo., v. 24, No. 1, March, 1929 (163 with 56 figs.).

The old "geological method" of predicting the existence of useful deposits has been supplemented in the last few years by the so-called "geophysical prospecting," methods by which the physical properties of rocks and minerals previously determined in the laboratory serve to facilitate the interpretation in terms of geology of disturbances of physical forces detected at the Earth's surface. As much of this work has been done by private companies and individuals and little has been published respecting its extent, an appeal was made to the various companies and persons engaged in geophysical prospecting and most of the statistical portion of the publication is based upon the information submitted by them. The object of the author is to describe the fundamental principles of geophysical prospecting and to show its actual extent and recent successes on this continent.

The principal part of the report is devoted to a description of the methods used in prospecting, and their extent, application, and success. These are: Gravity-methods (pendulum-apparatus, torsion-balance); magnetic and radioactive methods; geothermal measurements; seismic method; electrical methods (self-potential and resistivity methods, Schlumberger's direct-current field method, Lundberg's equipotential-line method, Elbof method, Lundberg's electromagnetic method, radiore method, and Sundberg's inductive method). All these are discussed in more or less detail and their operation and extent of employment usually made clear by means of figures and maps.

As to the depths reached by geophysical methods, the author gives the following figures for maximum depths reached under favorable conditions. With the torsion-balance it is possible to detect old buried formations down to over 5,000 feet, but the tops of salt-domes can not be detected deeper than 4,000 feet. The limit of the seismic method seems to be about 4,000 to 5,000 feet. With the magnetic method it seems possible to trace old deep-seated igneous massives easily down to 5,000 feet. The radioactive method has a very limited application as regards depth. As to the electrical methods most of the work has been done at very shallow depths—in mining no successful prospecting has been done with electric prospecting, as far as could be ascertained, at a depth greater than 500 to 800 feet. Very little is known as to how deep electric methods will go in detecting the effect of salt-water horizons in oil geology—probably not much over 1,000 feet. Rough estimates of the cost of geophysical prospecting by the different methods are given.

The last part of the publication consists of a statistical section containing lists of geophysical companies and consulting geophysicists as well as of manufacturers of geophysical instruments. It also contains a statistical review of recent geophysical activities in the United States, Mexico, and Canada.

On the whole it is a most comprehensive report on geophysical methods and operations in North America.

H. D. Harradon

THE MAGNETO-CHRONOGRAPH AND ITS APPLICATION TO MAGNETIC MEASUREMENTS[1]

By H. E. McComb and C. Huff

Abstract—The period of a magnet oscillating under the directive force of the Earth's magnetic field is a function of the strength of that field. Heretofore the estimation of the period has been accomplished by eye-and-ear readings but in the present method the personal equation is entirely eliminated. Light from an intense source such as an automobile headlight lamp is condensed on the glass-scale end of a magnetometer-magnet and after reflection is focussed on a slit in front of a photo-electric cell. The reflected beam acts as an optical lever whose period is the same as that of the magnet but whose amplitude is twice as great. At each transit of the image across the slit current is passed by the cell and after passing through amplifiers is made to operate a pen on a chronograph. A chronometer in the circuit marks seconds on the record by the same pen. In this investigation the method was applied in the determination of the moment of inertia of a magnetometer-magnet, estimation of personal equation in eye-and-ear readings, and in preliminary tests of the relative absolute magnetometer.

§ 1. In the determination of the absolute value of the horizontal intensity, H, of the Earth's magnetic field by the method of Gauss (oscillations and deflections) it is necessary, among other things, to know to a high degree of accuracy the value of the moment of inertia of the magnet-system as used in the oscillations. The error in the moment of inertia of the standard magnet may be as great or greater than in secondary instruments which may be referred to it for comparison of standards. It has not been customary to redetermine the moment of the standard magnet or secondary magnets at regular intervals, but only at such times as it was known definitely that changes had been made in the system by design, or that changes had occurred as a result of oxidation, accident, etc. The change in the moment of inertia due to oxidation or similar natural cause may or may not be linear with respect to time.

§ 2. The method usually followed in the determination of the moment of inertia of a magnet is described by Hazard.[2] This consists in the comparison of periods of a magnet-system while oscillating under the directive force of the Earth's field with and without the addition of a symmetrical mass whose moment of inertia may be computed from its dimensions. The moment of inertia, K, of the magnet-system is given by the relation

$$K = T_1^2\ K_1/(T_2^2 - T_1^2) \tag{1}$$

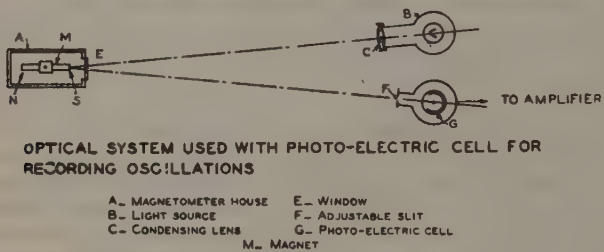
in which K_1 is the moment of inertia of the inertia-cylinder as computed from its dimensions at the observed temperature, and T_2 and T_1 are the periods of the oscillating system with and with-

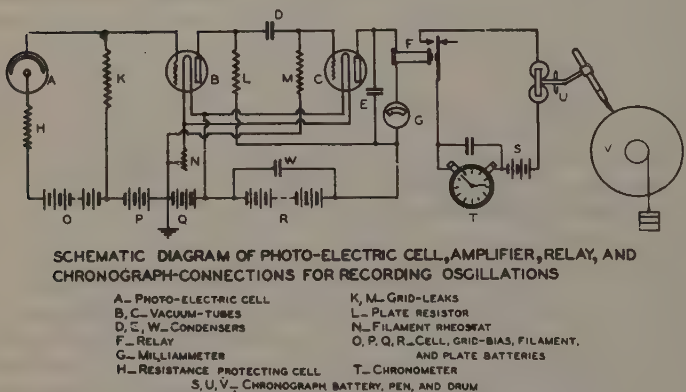
[1] Published with permission of the Director of the U. S. Coast and Geodetic Survey and the Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

[2] D. L. Hazard, Directions for magnetic measurements, pp. 24-27.

out the inertia-weight. The observations are combined in such a manner as to minimize the effects of changes in H, temperature, magnetic moment, and other factors which affect the period. In spite of greatest care in manipulation of the magnet-system and the inertia-weight and in the estimations of the period, the results have not been entirely satisfactory.

§ 3. In the present investigation an attempt has been made to determine periods to a much higher degree of accuracy than is possible by eye-and-ear methods in common use. Briefly stated, the method consists of the use of a photo-electric cell for indicating the precise times of transit of the oscillating magnet across the magnetic meridian. Referring to Figure 1, light from an intense source B (a 6-volt automobile headlight lamp) was condensed by





FIGS. 1 AND 2—Schematic diagrams for magneto-chronograph

a lens C on the glass-scale end of the oscillating magnet M and after reflection brought to focus on a window in front of a photo-electric cell.[3] Although the reflection takes place from the surface of a disc of plane glass whose diameter is about 8 mm, the extra light from this reflection which falls upon the photo-electric cell at each transit of the image across the cell causes sufficient current to

[3] Potassium hydride cell, commercially known as "Visitron 5," as supplied by the G-M Scientific Company, Chicago.

flow in the primary circuit, which, after amplification by a two-stage, resistance-coupled amplifier, will operate a sensitive relay which in turn operates the pen of a chronograph. The schematic diagram of the photo-electric cell, amplifier, relay, and chronograph is shown in Figure 2. The amplifier, orientation of light-source and cell with respect to magnetometer, and a more detailed view of lamp and cell with their housings are shown in Figures 3, 4, and 5. A protective resistance H of about 40,000 ohms is placed in series with the photo-electric cell A, which, under conditions imposed upon it in this work, operates best under a pressure of 135 volts supplied from three 45-volt radio B-batteries in series. The amplifier is of the resistance-coupled type, L and M each being a wire-wound grid-leak resistance of one megohm, and the coupling condenser D having a capacity of 0.1 microfarad. The resistance K is of the commercial grid-leak type, rated at ten megohms, but its actual measured value is 11.5 megohms. A negative bias of three volts is applied to the grid of the first stage. The grid-return of the second stage is brought back to the negative of the filament battery, thus applying a one-volt negative bias to the grid of the second stage. The vacuum-tubes are of the UX240 type. The condensers E and W are of the conventional by-pass type, and each has a capacity of 2 microfarads. The plate-battery R consists of three 45-volt radio B-batteries in series. Under best conditions the plate-current in the last stage drops from one milliampere to zero at each transit of the light-spot across the photo-electric cell. This change in current is sufficient to release the armature of a sensitive relay F[4]. This relay, as modified, operates on a current of 0.1 milliampere.

A siderial chronometer T, equipped with seconds time-break, is placed in series with the telephone-relay and the electromagnet operating the pen of the chronograph. This pen is operated in the same direction whether the circuit is broken by the relay of the amplifier or by the chronometer. The marks caused by the amplified photo-electric current are considerably longer than those made by the chronometer, and therefore easily identified. There were some cases in which the transit of the magnet was coincident with the time-mark of the chronometer and under such conditions the time of that particular transit could not be estimated; but these coincidences were so infrequent as to cause no serious inconvenience in reading the records.

§ 4. In the first determinations of the moment of inertia by this method the order of observations and the accomplishment of other details connected with the work were carried out in precisely the same manner as for eye-and-ear observations and with the same care. This series began with the oscillating system loaded with the inertia-cylinder, followed by an unloaded set, then loaded, etc., alternately, until there had been obtained eight sets loaded and seven sets unloaded. In each set the system was allowed to

[4] Graybar Electric Company telephone-relay, type G-11, 1500 ohms, rewound to 3000 ohms.

oscillate for ten minutes. A sample of one of the chronograms in this series is reproduced in Figure 6, considerably reduced. The chronograph was operated at its highest speed so that the velocity

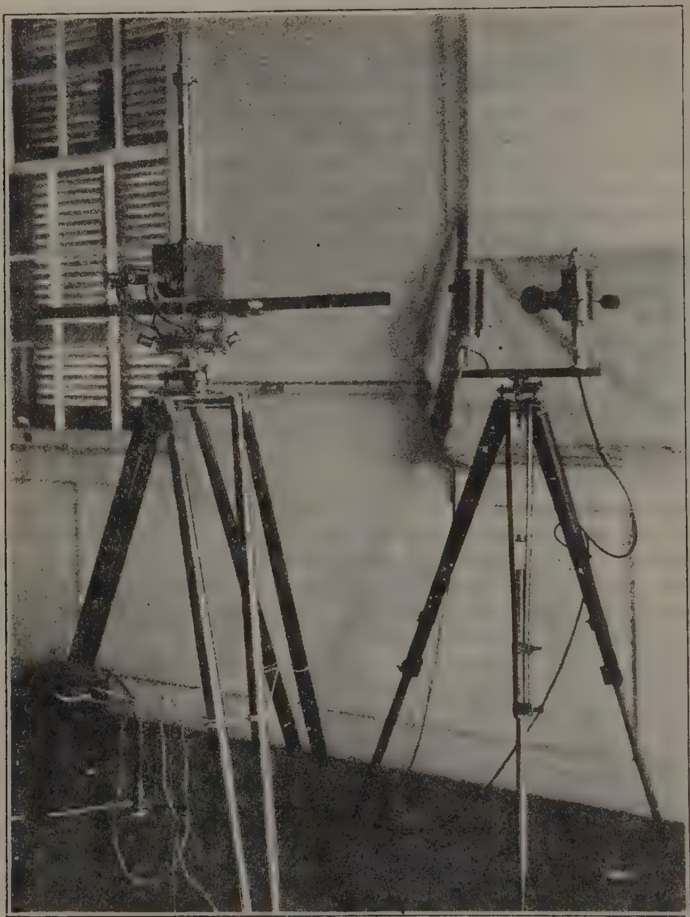


FIG. 3—Magnetometer and photo-electric cell with light-source as mounted for use

of the paper was about 19 mm per second. Each transit of the magnet across the meridian is faithfully recorded and the longer time-breaks are the result of these transits. The time of one oscillation of the loaded system was approximately 7.6 seconds, and of the unloaded system 4.6 seconds. The chronometer is so constructed that the fifty-ninth second is not marked. Unfortunately one tooth of the time-marking gear of the chronometer is defective and produced one long mark each minute, but this introduced very little inconvenience in interpreting the records.

The length of the break caused by the transit of the magnet is dependent upon the width of the slit in front of the cell, the width of the image or spot of light and its linear velocity as it passes the window. The length of this break was reduced to the smallest value possible for satisfactory operation of the relay and averaged about 0.2 second for the loaded sets. On account of the smallness of the aperture of the glass window of the magnet from which reflection takes place and the distance at which it was necessary to keep the light-source and photo-electric cell in order to reduce to a negligible amount the permanent and electro-magnetic effects on the oscillating magnet, it was not possible to obtain a small intense image. A long-focus lens placed directly in front of the reflecting glass window of the magnet produced a small sharp image equal in size to the object and at the same distance as the object when the condensing lens was removed, but the intensity of this image was not sufficiently great to operate the system with the amplifier available. The most satisfactory results were obtained when a large condensing lens was used near the source of light as shown in Figure 1, in spite of the fact that the image was highly magnified. The width of the slit as used in the most successful tests was 0.5 cm, the width of the image was about 1.0 cm; the total width of image and slit was therefore about 1.5 cm. Each set with system loaded was started with the spot oscillating through an arc whose chord was equal to 40 cm; with an average period of 9.1 seconds the velocity of the image at the time of transit at the beginning of a set was $40\pi/9.1$ or 13.9 cm/sec and dropped to half this velocity at the end of a set as the amplitude decreased to about 20 cm. For a loaded set with an average period of 15.2 seconds the velocity decreased from 8.3 cm/sec to 6.2 cm/sec, the range decreasing from 40 cm to 30 cm in ten minutes. The precise chronometer-time at which a sufficient portion of the image falls on the cell to excite a photo-electric current great enough to operate the relay is uncertain but a careful examination of all of the magnetograms made indicates that at a given velocity of light-spot the phase at which operation of the relay is positive is quite constant. The errors due to lags in the relays are reduced because time-intervals are used and these effects cancel. There may be a slight difference in the response of the relay at the beginning and end of a set due to the difference in the velocity of the spot as the amplitude dies down and the observations indicate that an error from this source may be present. The mean length of a photo-electric time-mark at the beginning of a loaded set is 0.18 second and the mean length at the end is 0.20 second, while they are 0.15 and 0.19 second for an unloaded set. Owing to the fact that the image and slit are necessarily wide for the magnet and optical systems used, it is very difficult to estimate the precise differential effects in the response of the amplifying system due to these changes in velocity of the light-spot across the cell. A change of magnetic declination during a set would introduce an error if transits in one direction only were used but in all cases successive transits were

scaled from the magnetograms, so that any error from this source is practically eliminated. Errors due to wide image and slit could be reduced to a very small and certainly negligible quantity by providing the oscillating system with a more efficient reflector such as a total reflecting prism and a long-focus lens near the reflector, just as is used in magnetographs. This method was given a trial in the first tests but in the final tests it seemed desirable for comparison purposes to use the magnet-system without alteration, and all results given in this article were obtained with the unaltered long magnet of Coast Survey (Cooke) magnetometer No. 36.

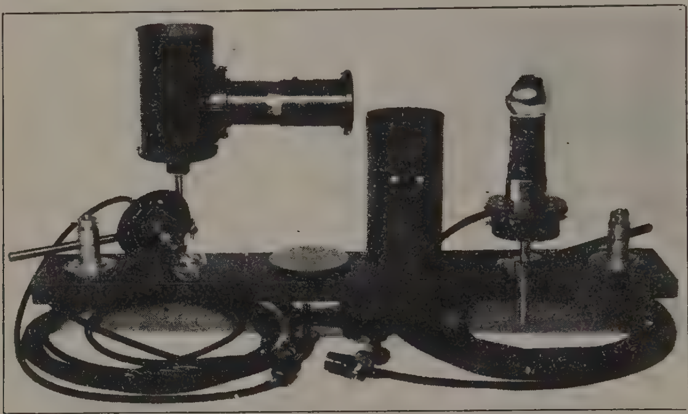


FIG. 4—Photo-electric cell and lamp with housing

§ 5. As a test of the efficiency and accuracy of the system for recording accurately the transits of the magnets, the times of all transits on 15 of the grams were scaled. Scalings were made directly from the grams by the use of a very accurate diagonally-ruled reading glass. The time of the beginning of any transit could be scaled to an accuracy of 0.02 second, and actual tests proved that scalings in most cases could be duplicated to an accuracy of 0.01 second. The results of all the scalings from two of the magnetograms are given in Table 1. This table is self-explanatory and shows that the means of the times for any definite number of oscillations are practically the same, in spite of the fact that the magnetogram shows that the day was slightly disturbed magnetically. Practically all of the tests were as satisfactory as these and indicate that the error in any time interval used was of the order of 0.02 second and, of course, much smaller for the means of each series, while they may be as great as 0.2 second for the best eye-and-ear readings with correspondingly smaller probable error in the mean. A sample set of eye-and-ear readings with this same magnetometer is given in Table 2. The probable errors in the means by the two methods show the graphical

TABLE 1—*Times scaled from chronogram in test No. 3 for all transits long magnet of magnetometer No. 36 at Cheltenham, Maryland, November 17, 1928*

Magnet	No.[a]	Time (t_1)	No.[a]	Time (t_2)	Time 40 oscillations (t_2-t_1)	Means
		s		s	s	s
With bar	0	00.73	40	305.65	304.92	
	1	08.43	41	313.41	*.98*	304.95
	2	15.97	42	320.90	.93	
	3	23.69	43	328.63	*.94*	.94
	4	31.21	44	336.16	.95	
	5	38.94	45	343.88	*.94*	.94
	6	46.44	46	351.40	.96	
	7	54.19	47	359.14	*.95*	.96
	8	61.70	48	366.64	.94	
	9	69.43	49	374.39	*.96*	.95
	10	76.95	50	381.88	.93	
	11	84.69	51	389.63	*.94*	.94
	12	92.20	52	397.13	.93	
	13	99.93	53	404.88	*.95*	.94
	14	107.43	54	412.37	.94	
	15	115.16	55	420.12	*.96*	.95
	16	122.70	56	427.60	.90	
	17	130.43	57	435.39	*.96*	.93
	18	137.94	58	442.83	.89	
	19	145.65	59	449.61	*.96*	.92
	20	153.18	60	458.08	.90	
	21	160.92	61	465.86	*.94*	.92
	22	168.40	62	473.33	.93	
	23	176.18	63	481.10	*.92*	.92
	24	183.68	64	488.60	.92	
	25	191.42	65	496.36	*.94*	.93
	26	198.93	66	503.82	.89	
	27	206.67	67	511.60	*.93*	.91
	28	214.18	68	519.06	.88	
	29	221.90	69	526.85	*.95*	.92
	30	229.42	70	534.31	.89	
	31	237.15	71	542.08	*.93*	.91
	32	244.67	72	549.56	.89	
	33	252.40	73	557.34	*.94*	.92
	34	259.90	74	564.80	.90	
	35	267.65	75	571.58	*.93*	.92
	36	275.15	76	579.06	.91	
	37	282.91	77	586.82	*.91*	.91
	38	290.40	78	595.29	.89	
	39	298.15	79	603.07	*.92*	.90

Mean time, 40 oscillations with bar......... 304.929
Mean time, one oscillation................. 7.62322
Probable error, time one oscillation.........±0.00011

[a] Odd-numbered transits are from right, even-numbered are from left.

Table 1—*Continued*

Magnet	No.[a]	Time (t_1)	No.[a]	Time (t_2)	Time 66 oscillations (t_2-t_1)	Means
		s		s	s	s
Without bar	0	00.86	66	303.39	302.53	
	1	05.50	67	308.04	.54	302.54
	2	10.03	68	312.55	.52	
	3	14.67	69	317.20	.53	.52
	4	19.19	70	321.71	.52	
	5	23.84	71	326.38	.54	.53
	6	28.35	72	330.89	.54	
	7	33.00	73	335.54	.54	.54
	8	37.53	74	340.05	.52	
	9	42.19	75	344.71	.52	.52
	10	46.69	76	349.22	.53	
	11	51.35	77	353.88	.53	.53
	12	55.85	78	358.40	.55	
	13	60.52	79	363.03	.51	.53
	14	65.00	80	367.55	.55	
	15	69.69	81	372.22	.53	.54
	16	74.19	82	376.71	.52	
	17	78.85	83	381.36	.51	.52
	18	83.36	84	385.90	.54	
	19	88.00	85	390.53	.53	.54
	20	92.51	86	395.03	.52	
	21	97.19	87	399.70	.51	.52
	22	101.70	88	404.23	.53	
	23	106.37	89	408.86	.49	.51
	24	110.85	90	413.40	.55	
	25	115.52	91	418.02	.50	.52
	26	120.00	92	422.55	.55	
	27	124.70	93	427.20	.50	.52
	28	129.28	94	431.73	.55	
	29	133.85	95	436.37	.49	.52
	30	138.47	96	440.90	.43	
	31	143.01	97	445.53	.52	.48
	32	147.51	98	450.06	.55	
	33	152.19	99	454.70	.51	.53
	34	156.70	100	459.23	.53	
	35	161.37	101	463.86	.49	.51
	36	165.86	102	468.40	.54	
	37	170.52	103	473.03	.51	.52
	38	175.00	104	477.57	.57	
	39	179.70	105	482.20	.50	.54
	40	184.20	106	486.73	.53	
	41	188.86	107	491.37	.51	.52
	42	193.38	108	495.90	.52	
	43	198.02	109	500.53	.51	.52
	44	202.52	110	505.06	.54	
	45	207.20	111	509.70	.50	.52
	46	211.70	112	514.22	.52	
	47	216.35	113	518.87	.52	.52
	48	220.87	114	523.40	.53	
	49	225.53	115	528.03	.50	.52
	50	230.02	116	532.57	.55	
	51	234.70	117	537.20	.50	.52
	52	239.20	118	541.73	.53	
	53	243.87	119	546.36	.49	.51

TABLE 1—*Concluded*

Magnet	No.[a]	Time (t_1)	No.[a]	Time (t_2)	Time 66 oscillations (t_2-t_1)	Means
		s		s	s	s
Without bar	54	248.39	120	550.90	302.51	
	55	253.02	121	555.54	*.52*	302.52
	56	257.54	122	560.07	.53	
	57	262.19	123	564.71	*.52*	.52
	58	266.71	124	569.22	.51	
	59	271.37	125	573.89	*.52*	.52
	60	275.89	126	578.40	.51	
	61	280.54	127	583.03	*.49*	.50
	62	285.01	128	587.55	.54	
	63	289.70	129	592.20	*.50*	.52
	64	294.22	130	596.73	.51	
	65	298.86	131	601.38	*.52*	.52

Mean time, 66 oscillations without bar...... 302.522
Mean time, one oscillation.................. 4.58367
Probable error, time one oscillation.........±0.00005

TABLE 2—*Period of unloaded magnet-system from eye-and-ear readings for long magnet, magnometer No. 36, at Cheltemham, Maryland, September 13, 1928*

No.	Time			No.	Time			Time 100 oscil'ns	
	h	m	s		h	m	s	m	s
0	14	12	35.2	100	14	20	12.5	7	37.3
5			58.1	105			35.4		.3
10		13	20.9	110			58.2		.3
15			43.8	115		21	21.1		.3
20		14	06.6	120			44.0		.4
25			29.5	125		22	06.8		.3
30			52.3	130			29.6		.3
35		15	15.3	135			52.5		.2
40			38.1	140		23	15.5		.4
45		16	01.1	145			38.4		.3

Mean time, 100 oscillations without bar....... 7 37.31
Mean time, one oscillation................... 4.5731
Probable error, time one oscillation........... .00063

method to be superior. In order to secure maximum accuracy from the magnetograms the method as described by McFarland[5] was followed as closely as convenient. For convenience the equation derived by McFarland is repeated. Maximum accuracy is secured when

$$k=2n/3+1 \tag{2}$$

in which n is the total number of observations in the series and

[5] W. N. McFarland, *Terr. Mag.*, v. 34, 1929 (67-72).

k is the number of the observations at which the subtractions are started.

§ 6. For the observations with the magnet loaded there were about 80 transits in ten minutes and for the unloaded there were about 130 transits in ten minutes. Each series of loaded was divided at the sixtieth transit which gave about 20 pairs of oscillations right and left and each set of unloaded observations was divided at the one-hundredth transit which gave about 30 pairs. For the sake of uniformity in the computations all values of the times of one oscillation were carried to the fifth place in decimals, although it is apparent that there is some uncertainty in the fourth place. It may be stated in passing that the results given in the summaries for moment of inertia are taken from a total of over 3,000 scalings. Fully as many more scalings were made in other phases of this investigation.

§ 7. Tables 3 and 3*a* are summaries of the observations as scaled from the first series of alternate loaded and unloaded observations using the magneto-chronograph. The periods are combined in the manner described by Hazard[2] and the resulting values of the moment of inertia, K, of the magnet system reduced to 16° are shown in column 7 of Table 3*a*. In the last column is shown a series of values of log K as determined by eye-and-ear observations. These results indicate that somewhat greater accuracy has been obtained by the new method. In this first series, as well as in the series by eye-and-ear method, great care was taken to

TABLE 3—*Summary of observations with magneto-chronograph for moment of inertia of long magnet of magnetometer No. 36 (inertia-bar No. 275) at Cheltenham, Maryland, November 17, 1928*

Test No.	Time beginning	H-ordinate	H	Observed temp. magnet	Time, one oscillation from chronogram: Loaded (T_2') mean of 20	Unloaded (T_1') mean of 30
	h m	γ	γ	°	*s*	*s*
1	8 18	103	18658	16.1	7.62250	
2	8 33	101	56	16.0		4.58335
3	8 52	107	62	16.0	7.62313	
4	9 07	109	64	15.8		4.58269
5	9 25	107	62	16.0	7.62398	
6	9 51	101	56	16.0		4.58361
7	10 05	81	36	16.1	7.62899	
8	10 19	66	21	16.2		4.58839
9	10 35	66	21	16.6	7.63338	
10	10 48	69	24	16.7		4.58857
11	11 04	78	33	17.0	7.63077	
12	11 16	91	46	17.1		4.58654
13	11 29	93	48	17.4	7.62795	
14	11 42	97	52	17.6		4.58589
15	11 55	95	50	17.9	7.62883	

TABLE 3a—*Computation of moment of inertia from results in Table 3 combined according to Hazard's method after applying corrections* [a]

Test No.	Corrected log T_2^2 and log T_1^2	T_2^2 and (T_2^2)	T_1^2 and $(T^2)-T_1^2$	log T_1^2 and log K_1	log $(T_1^2 K_1)$ and log $[(T_2^2)-T_1^2]$	log K at 16°	log K from eye-and-ear readings at 20°
1	1.76281	57.9175					
2	1.32073	(57.9235)	20.9281	1.32073	3.96736		
3	1.76290	57.9295	36.9954	2.64663	1.56815	2.39921	2.39914
4	1.32064	(57.9362)	20.9238	1.32064	3.96727		911
5	1.76300	57.9429	37.0124	2.64663	1.56835	892	947
6	1.32077	(57.9796)	20.9300	1.32077	3.96740		913
7	1.76355	58.0163	37.0496	2.64663	1.56878	862	945
8	1.32164	(58.0441)	20.9720	1.32164	3.96827		919
9	1.76396	58.0719	37.0721	2.64663	1.56905	922	933
10	1.32159	(58.0468)	20.9696	1.32159	3.96823		902
11	1.76359	58.0216	37.0772	2.64664	1.56911	912	907
12	1.32114	(57.9956)	20.9479	1.32114	3.96778		935
13	1.76320	57.9696	37.0477	2.64664	1.56876	902	961
14	1.32093	(57.9702)	20.9377	1.32093	3.96758		958
15	1.76321	57.9709	37.0325	2.64665	1.56858	900	980
	Means....................................					2.39902	2.39933
	Resulting mean value log K at 20°...........					2.39906	....

[a] $T_2=(T_2')$ corrected according to the equation $HM=\pi^2 K/[T^2 (1+0.0000116d)^2 (5400/(5400-h)) (1+(t-t')q) (1+\mu H/M]$ in which H is the horizontal intensity, M the magnetic moment, d the rate of the chronometer in seconds per day, h the angle through which the magnet is turned when the torsion-head is turned through an angle of 90°, q the temperature-coefficient, t' the observed temperature of the oscillating magnet, t the temperature to which the observations are referred as standard, μ the induction-coefficient.

balance the inertia-weight accurately in every case so that the axis of the system oscillated in the same horizontal plane to an accuracy of at least one minute of arc, as shown by the horizontal index-mark on the magnet relative to the horizontal line in the diaphragm of the telescope. Also in both series the inertia-weight was reversed in each alternate loaded set so that if there were any traces of permanent magnetism in the weight this method would tend to reveal its presence. No systematic differences by reversals are apparent. Temperatures were observed at the beginning and end of each series and great care was taken to make all observations uniform with respect to time.

§ 8. Some further tests were made about one month later with the same apparatus throughout. However, in these observations tests were made to ascertain the accuracy of timing of both loaded and unloaded sets, that is, the sets were made in the following order: 11 sets loaded, 17 sets unloaded, 2 sets loaded, 6 sets unloaded but with inertia bar eccentric by an amount sufficient to tilt the axis of the oscillating system ten minutes of arc, 5 sets with inertia-weight balanced, and finally 11 sets with system alternately loaded and unloaded. For all observations in December it was possible to estimate more accurately the value of

TABLE 4—*Summary of observations with magneto-chronograph for moment of inertia, long magnet magnetometer No. 36 at Cheltenham, Maryland, December 20-21, 1928* [a]

Date	Test No.	Time beginning	H	Temp. magnet	Scaled time one oscil'n (T_2') and (T_1')	Corrected log T_2^2 and log T_1^2	log (T_2^2H) and log (T_1^2H)
1928		h m	γ	°			
Dec. 20							
Loaded	16	14 22	18676	8.50	7.60605	1.76034	1.03162
	17	14 43	75	8.70	630	6033	159
	18	15 04	78	8.60	592	6030	163
	19	15 29	82	9.50	423	5995	137
	20	15 45	84	9.50	497	6003	150
					Means	1.76019	1.03154
Dec.20							
Loaded	21	18 22	18685	8.20	7.60467	1.76023	1.03172
	22	18 33	86	8.30	497	6024	176
	23	18 45	86	8.50	453	6016	168
	24	18 56	86	8.60	450	6014	166
	25	19 07	87	8.60	472	6017	171
	26	19 18	87	8.65	497	6018	172
					Means	1.76019	1.03171
Dec. 20							
Unloaded	27	19 54	18687	9.10	4.57282	1.31800	0.58954
	28	20 05	87	9.20	272	796	950
	29	20 16	88	9.20	255	793	949
	30	20 27	89	9.15	256	794	953
	31	20 38	90	9.10	242	793	954
					Means	1.31795	0.58952
Dec. 20							
Unloaded	32	21 38	18683	8.80	4.57245	1.31798	0.58943
	33	21 49	80	8.60	299	813	951
	34	22 00	79	8.60	327	818	953
	35	22 11	78	8.55	341	822	955
	36	22 22	78	8.50	345	823	956
	37	22 33	79	8.50	323	819	954
					Means	1.31816	0.58952
Dec. 21							
Unloaded	38	7 16	18698	2.10	4.56546	1.31785	0.58965
	39	7 27	97	2.35	544	780	957
	40	7 38	98	2.50	549	778	958
	41	7 49	98	2.55	556	779	959
	42	8 00	95	2.70	593	783	956
	43	8 11	95	2.65	579	782	955
					Means	1.31781	0.58958
Dec. 21							
Loaded	44	8 51	18687	2.60	7.59518	1.76015	1.03169
Balanced	45	9 48	76	2.30	760	047	175
					Means	1.76031	1.03172

[a] The observations are combined as described in section 8.

TABLE 4—*Concluded*

Date	Test No.	Time beginning	H	Temp. magnet	Scaled time one oscil'n (T_2') and (T_1')	Corrected log T_2^2 and log T_1^2	log (T_2^2H) and log (T_1^2H)
1928		*h m*	γ	°			
Dec. 21							
Loaded	46	10 16	18678	2.55	7.59743	1.76041	1.03174
Unbalanced	47	10 27	78	2.45	705	038	171
	48	10 38	76	2.35	677	037	165
	49	10 49	76	2.25	652	036	164
	50	11 00	74	2.15	702	044	168
	51	11 11	73	2.10	770	041	162
					Means	1.76040	1.03167
Dec. 21							
Loaded	52	11 31	18664	2.50	7.60062	1.76078	1.03178
Balanced	53	11 42	63	2.50	7.60035	075	173
	54	11 53	62	2.50	7.59975	068	164
	55	12 54	48	2.50	7.60253	100	163
	56	13 05	39	2.55	7.60423	119	161
					Means	1.76088	1.03168
Dec. 21							
Loaded	57	13 19	18645	2.70	7.60305	1.76103	1.03159
Unloaded	58	13 34	51	3.20	4.57130	1.31876	0.58946
Loaded	59	13 52	55	3.70	7.60495	1.76106	1.03186
Unloaded	60	14 07	58	4.10	4.57168	1.31868	0.58955
Loaded	61	14 23	63	4.40	7.60308	1.76073	1.03171
Unloaded	62	14 38	66	4.60	4.57072	1.31840	0.58945
Loaded	63	14 53	66	5.40	7.60857	1.76118	1.03223
Unloaded	64	15 08	70	5.20	4.57100	1.31835	0.58949
Loaded	65	15 24	72	5.40	7.60627	1.76093	1.03212
Unloaded	66	15 38	76	5.20	4.57006	1.31817	0.58945
Loaded	67	15 53	75	5.70	7.60342	1.76054	1.03180
					Means loaded..................	1.76091	1.03188
					Means unloaded...............	1.31847	0.58948

The resulting values of log K at 4°.5 computed as in Table 3*a* are respectively 2.39876, 2.39888, 2.39836, 2.39813, 2.39835, giving a mean of 2.39850 which reduced to 20° gives log K=2.39866.

H from the magnetograms as an artificial time-break was installed on the Eschenhagen magnetograph so that the light was eclipsed for one minute before the chronograph-record was started and again at the end of each ten-minute run. The segment of the H-curve between these breaks corresponded to the oscillations recorded on the chronogram during this interval. From these ordinates and other data furnished by the Cheltenham Observatory staff the absolute values of H were computed. Errors due to overlap of H-curve on base-line were eliminated by use of the artificial breaks. A summary of results is given in Table 4. This table shows: Character and number of the test; standard time of beginning of each ten-minute run; absolute value of H; mean temperature of magnetometer magnet during each set; time of

TABLE 5—*Summary of Results in Table 4*

Tests No.	Magnet-system loaded			Magnet-system unloaded	
	log H_2	log T_2^2	log (T_2^2H)	log H_1	log (T_1^2H)
16–20	9.27135	1.76019	1.03154		
21–26	152	019	171		
27–31				9.27157	0.58952
32–37				136	952
38–43				177	958
44–45	141	031	172		
46–51	128	040	167		
52–56	080	088	168		
57–67	097	091	188	101	948
Means	9.27122	1.76048	1.03170	9.27143	0.58952

Computation of log K

log (T_1^2H)	0.58952	log T_2^2	1.76048	log $(T_2^2-T_1^2)$	1.56581
log H_2	9.27122	T_2^2	57.6084	log $(T_1^2K_1)$	3.96476
log T_1^2	1.31830	T_1^2	20.8113	log K at 5°	2.39895
log K at 5°	2.64646	$T_2^2-T_1^2$	36.7971	log K at 20°	2.39910
log $(T_1^2K_1)$	3.96476	log $(T_2^2-T_1^2)$	1.56581		

one oscillation as scaled from chronogram (the November observations were first reduced to 16° *C*, while the December observations were first reduced to 5° *C*, and finally all observations were reduced to 20° *C*); values of log T^2 corrected for arc, rate of chronometer, torsion, induction, and temperature (see p. 138 for values of corrections); and log T^2H, which should be constant for each type of observation provided there has been no permanent loss of magnetism of the oscillating magnet. The results of all of the December observations are summarized in Table 5. In order to compute the moment of inertia the logarithm of the means of the separate terms may be taken as equal to the mean logarithm without introducing appreciable error, so that the value of K was computed from the means in the following manner: The value of log (T_1^2H) was combined with the value of H_2 (the value corresponding to the time of oscillation T_2) to give a value of log T_1^2 corrected for the mean value of H for the loaded series. The moment of inertia K of the magnet-system was then computed using this corrected value of T_1^2 for T_1^2 in equation (1), K_1 reduced to 5°, and T_2^2 as computed from the mean log T_2^2 in Table 6.

§ 9. The values of T^2H for the December observations are fairly constant with the exception of series 21 to 26 (loaded) and the three sets from 57 to 67 (loaded). It was expected that these last values of log K as computed by Hazard's method would be in better agreement than in the first series, as the day was less disturbed magnetically and the extra time-marks were used on the

TABLE 6—*Personal-equation tests showing comparisons of times for one oscillation long magnet magnometer No. 36 from chronogram and from eye-and-ear readings at Cheltenham, Maryland, November 13-22, 1928*

Test No.	Time one oscillation		dt on T_0	Test No.	Time one oscillation		dt on T_0
	Chronograph (T_0)	Obs'r (G)			Chronograph (T_0)	Obs'r (M)	
	s	*s*	*s*		*s*	*s*	*s*
2	4.58787	4.58787	0.00000	1	4.58423	4.58390	+0.00033
3	8732	8732	000	2	8787	8732	+ 055
4	8796	8821	− 025	3	8732	8750	− 018
6	8846	8857	− 011	4	8796	8714	+ 082
9	8597	8607	− 010	8	9062	8130	− 068
10	8857	8857	000	12	7308	7304	+ 004
11	7271	7214	+ 057	13	7427	7446	− 019
12	7308	7161	+ 147	14	7507	7575	− 068
13	7427	7464	− 037	15	7538	7550	− 012
14	7507	7475	+ 032	16	7534	7600	− 066
15	7538	7425	+ 113	17	8710	8800	− 090
16	7534	7625	− 091	18	8676	8780	− 104
				19	8684	8710	− 026
Means without regard to sign			0.00044	....			0.00050
Means having regard to sign			+0.00015	....			−0.00023
		Obs'r (S)				Obs'r (B)	
2	4.58787	4.58732	+0.00055	11	4.57271	4.57304	−0.00033
4	796	8839	− 043	12	308	232	+ 076
5	867	9000	− 133	13	427	411	+ 016
7	827	8893	− 066	14	507	550	− 043
				15	638	450	+ 088
				16	534	525	+ 009
Means without regard to sign			0.00074	....			0.00044
Means with regard to sign			−0.00047	....			+0.00019

magnetograph, but the deviations are greater. It is believed that the large deviations are not due to the non-uniform rate of the chronometer over short periods or to defects in the magneto-chronograph system as a whole, but rather to temperature-control, possible variable temperature-coefficient of the magnet, or to errors in the value of H. The variometer from which the values of H were obtained has recently been compensated for temperature and the scale-value is slowly decreasing. A slight uncertainty in either of these factors would account for some of the difference. On the whole, however, it would seem that the greatest trouble lies in the uncertain temperatures of the oscillating magnet of the magnetometer. The induction-factor, log $(1+\mu H/M)$, was taken as constant all through both series. The temperature-coefficient had been checked by previous observations and agreed very well with values previously determined from routine absolute observations at the Honolulu Observatory. The torsion-factor was checked

several times during the series both for the loaded and unloaded system and there was a very close agreement in the different sets, so that the mean values were used for all computations. The rate of the chronometer (siderial) was very high but unusually uniform as referred to daily signals received by radio from Arlington. The maximum difference in daily rate over two months was only 2.8 sec/day while the maximum difference for any two successive days in this interval was only 1.8 sec/day, the average being much less. This chronometer was also checked against a chronometer at the Bureau of Standards, both recording simultaneously on a chronograph. It was stated at the Bureau of Standards that its chronometer was accurate to one part in 200,000 over any interval. The comparison covered an interval of about two hours with the chronograph operating at high and low speeds and the magnetograms indicate that the chronometer used in this magnetic work was as uniform in its operation as that of the Bureau of Standards. This indicates, but of course does not prove, that the chronometer used in these tests had a rate which was as uniform over the short intervals as over any 24-hour interval. In the tests during November the distance from the axis of rotation of the magnet to the photo-electric cell was 147 cm, while for those in December it was 165 cm. The miscellaneous data required for the detailed computations are as follows: Moment of inertia for inertia-bar No. 275, log K_1 at $20° = 2.64669$ with change per 1° change in temperature 0.000016; H scale-values and base-lines, 2.88 and 2.80 gammas and 18556 and 18558 gammas, respectively, on November 17 and December 20-21; corrections to infinitesimal arc for system loaded, 0.00022 and 0.00018 second and for system unloaded, 0.00016 and 0.00013 second, respectively, on November 17 and December 20-21. (The corrections for reduction to infinitesimal arcs are computed from the relation $dt = (1 - a^2/64)$ in which a is the average arc of one oscillation expressed in radians and dt the correction in seconds; the chord was taken as equal to the arc so that the corrections are on the basis that the angle through which the magnet oscillates is one-half that of the reflected ray.) Other corrections common to all observations are: Rate of chronometer, log $(1 - .0000116\ d)^2$, 0.00325; torsion loaded, log $(5400/(5400\text{-}h)$, 0.00094; torsion unloaded, 0.00067; induction, log $(1 + \mu H/M)$, 0.00097; temperature, log $(1-(t-t')q) = 0.000178$ $(t-t')$ in which t' is the observed temperature and t is the temperature to which the observations are referred.

§ 10. Several series of period-observations of the transit of the light-spot across the slit of the photo-electric cell were made by the eye-and-ear method, all transits being recorded also by the magneto-chronograph to test for personal equation. A screen was placed in front of the slit until just a moment before the first transit, at which time the screen was removed, so that there was no difficulty in identifying the observed transit time-breaks on the chronogram. The light was eclipsed again immediately following the last observed transit, which served as another check. Four different observers (G, B, M, and S) made observations in this manner. The results are summarized in Table 6 showing the

mean times of one oscillation computed from the chronograph-scalings, mean times as estimated by observers, and the departures (plus or minus) of the observer's estimate from that recorded by the magneto-chronograph. All computations were carried to the fifth place of decimals for convenience of comparisons. Each time of one oscillation is a mean of eight pairs of transits, four right and four left, and for a range of 70 oscillations. The means are taken

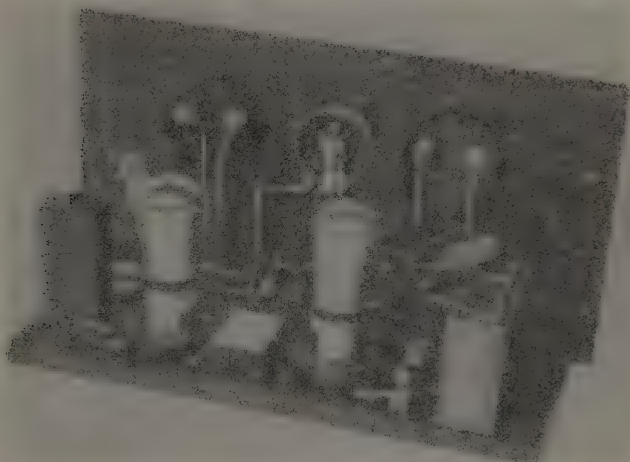


FIG. 5—Amplifier

with and without regard to sign. Those tests having the same number (first column) were made simultaneously, that is, the different observers were observing the same spot at the same time. The same chronometer which marked time on the chronogram was used in these eye-and-ear observations, the timing circuit having been extended from the recording room to the observatory. The mean deviation without regard to sign for all four observers is 0.00050 second.

§ 11. The maximum deviation from the value obtained by the magneto-chronograph was 0.00147 second and the mean deviation without regard to sign was approximately the same for all observers, that is, about 0.0005 second. It has been shown by McFarland[5] that $r_0 = (T_0/H)\, r_H$, in which an error of r_0 in the time of one oscillation T_0 will produce an error of r_H in the value of H when the oscillation- and deflection-observations are combined for the computation of H. According to this equation an error of 0.00024 second in the time of the oscillation will produce an error of one gamma in the computed value of H at Cheltenham with the magnet used in this series. The maximum error in Table 6 would have resulted in an error of six gammas in H, while the mean error would correspond to an error of two gammas.

§ 12. Referring now to Table 1, in which it was estimated that the observed error of each interval of 40 oscillations was 0.02 second, the probable error in the mean time of one oscillation

Fig. 6—Magneto-chronogram obtained at Cheltenham Magnetic Observatory, November 17, 1928, of oscillation-periods for loaded and unloaded magnet 36 to determine its moment of inertia

would be 0.00011 second for a loaded set and 0.00005 second for an unloaded set, as shown on page 131. For a set, unloaded, by eye-and-ear method, the probable error would be 0.00063 second, so that the observational errors in timing were decreased considerably by use of the magneto-chronograph.

§ 13. The magneto-chronograph was operated practically every day during December, 1928, for one or two determinations of the period of the long magnet of magnetometer No. 36. During this interval there were fairly large ranges of temperature and horizontal intensity. The scaled periods were combined with the corresponding values of H (from magnetograph) as in Table 4, in order to see if the value of T^2H would be fairly constant after making allowance for gradual loss of magnetism of the oscillating magnet. The final values of T^2H varied over such a wide range that the results as a whole were not entirely satisfactory. In order to obtain uniform results by this method the conditions imposed upon the magneto-chronograph should be as uniform as it is possible to make them at every step of the operation. Also the temperature-coefficient must be accurately known as the observations are generally made over wide ranges of temperature and for purposes of comparison they must be reduced to the same standard.

§ 14. *Conclusions*—Considering the fact that all of the observations made during these tests were completed without any alterations whatsoever in the magnetometer or its magnets and that the clear glass window of the oscillating magnet was used as a reflector, the results as a whole agree as well as could be expected and seem to indicate that the magneto-chronograph may be used to advantage in certain phases of magnetic measurements. It would be interesting to repeat the tests with a special magnet-system equipped with a fairly large total-reflecting prism incorporated permanently in the stirrup so that a very narrow, intense image might be obtained, the intensity of which would be sufficient for operation of the photo-electric cell and amplifiers and so that a very narrow slit might be used in front of the cell. This would permit of operation at a greater distance from the magnetometer and the amplitudes could be reduced so that corrections to infinitesimal arc would be unnecessary. Under such conditions any possible error in the derived periods, as a result of different velocities at the times of transit, would certainly be reduced to negligible values. It is believed that the greatest source of error and the one which is most difficult of control, without a special magnet-house designed to eliminate large and sudden temperature-changes, lies in the uncertain and inconstant temperatures of the oscillating magnet.

§ 15. This investigation was done cooperatively by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and the United States Coast and Geodetic Survey. The authors wish to acknowledge their indebtedness to different members of the staffs of these two institutions and of the United States Bureau of Standards for many helpful suggestions.

United States Coast and Geodetic Survey and
Carnegie Institution of Washington,
Washington, D. C.

NOTES

(See also page 165)

9. *International Research Council*—Sir *Arthur Schuster* has been obliged, on account of ill health, to resign his post as Secretary General of the International Research Council and the Council has chosen in his stead Sir *Henry Lyons*, who has also been nominated Foreign Secretary of the Royal Society of London and has asked to be relieved of his secretaryship of the International Geodetic and Geophysical Union. The Executive Committee of the Union has warmly supported as candidate for the post, Colonel H. Winterbotham, Chief of the Geographic Section of the War Office, London, whose election will be submitted for ratification at the next general assembly of the Union in 1930.

10. *French Geodetic and Geophysical Union*—We have read with much interest the report of the proceedings of the meeting of the French National Committee of Geodesy and Geophysics on July 2, 1928. Of particular interest is the report on the work done in terrestrial magnetism and electricity in France and in the French colonial possessions. In Algeria, M. Lasserre, director of the Meteorological Service, has occupied 42 stations, distributed over the whole country. In Tunisia, Morocco, French West Africa, and Oceania magnetic observations have also been secured. The project of equipping a magnetic observatory at Dakar is now under consideration and the necessary credits for this purpose may be included in the budget for 1929. The following resolution passed by the French Section of Terrestrial Magnetism and Electricity at its meeting on June 28, 1928, will be of interest to readers of the Journal:

"La Section de Magnétisme et Electricité terrestres, se fondant sur les considérations suivantes:

"En France vient d'être établi un Réseau magnétique qui est le plus complet des Réseaux nationaux; des mesures magnétiques sont en cours ou en projet dans les possessions françaises réparties à la surface du Globe, mais les corrections que comportent ces mesures ne peuvent être faites dans de bonnes conditions que s'il existe dans la région un Observatoire magnétique où les variations des éléments magnétiques sont étudiées de manière régulière; cette étude est d'un grand intérêt au point de vue de celle de la propagation des ondes électro-magnétiques; d'ailleurs les observations relatives à l'électricité atmosphérique sont aussi d'une grande importance pour l'étude des propriétés électro-magnétiques de l'atmosphère;

"Emet le voeu

"Que des stations magnétiques soient créées en plusieurs points des possessions françaises, et que les observations relatives à l'électricité atmosphérique soient aussi développées."

An account is also given of the atmospheric-electric investigations now in progress at Val-Joyeux and Puy-de-Dôme as well as of certain studies which have been made by individual investigators.

THE VARIATION OF MAGNETIC ANOMALIES[1]

By W. N. McFarland

Abstract—This paper describes briefly a method of isogonic chart construction, and the distribution of station anomalies, or differences of observed values from the average condition shown by the chart. The distribution is shown to be according to the law of occurrence of accidental errors. The available data are given in a table and a figure shows the correspondence of observational data and theoretical curve in an individual case.

When magnetic anomalies are considered in collections of considerable size, they seem to be subject to a law of occurrence which is the same as that first derived to express the occurrence of errors in measurement. Inasmuch as this same law has been found to apply to variations in other natural phenomena and is inherent in any system of residuals derived from arithmetic means, it is to be expected perhaps that the variation of magnetic anomalies should come under the same rule. Mathematically the law is expressed by the formula

$$y = ke^{(-h^2x^2)}$$

and when drawn as a graph it is known as the probability-curve. The ordinate y in this application is the number of anomalies in a group of a given range, and the abscissa x is the average anomaly of the group. The constants h and k are peculiar to the individual case, and vary with the region of the observations and also with the number of observations used.

The anomalies which are taken as the basis of this conclusion are all anomalies in declination, so that in strictness the conclusion should not be extended to include inclination or intensity. However, it seems reasonable to expect that these other elements might be similarly distributed. As far as is apparent their occurrence is just as accidental, within the meaning of this word as it is applied to errors. The only requirement would be that enough anomalies be considered together to allow the law to manifest itself. It is perhaps pertinent to make some definition of magnetic anomaly as the term is used here, and to state the method of arriving at the numerical values.

An isogonic chart shows the geographic distribution of the declination in a manner similar to that in which a topographic map shows elevations, or even more closely as a mariner's chart shows depths. It is perhaps easier to visualize conditions in the case of topography. In any case the data for the construction of the map is a series of points fixed by latitude and longitude or some other kind of coordinates, and for these points measured values of the quantity to be represented. There is, however, one important difference. The engineer has the configuration of the ground before his eyes, can pick out critical points such as maxima and minima, or points where there is a change of gradient, and can accumulate data economically for as exact a representation of the topography as he may desire. However, the magnetic observer can pay no attention to critical points. His stations are selected by regard for other considerations, and the result is data comparable to that which would be available for the construction of a

[1] Published by permission of the Director of the United States Coast and Geodetic Survey.

topographic map if the elevations were taken at random. The problem when an isogonic chart is to be constructed is one of using the observations for what they can represent.

A little consideration will make it evident that drawing the isogonic lines so as to fit the observations exactly is not a representation of any real distribution. This will become apparent if subsequent observations are plotted on a chart so constructed. Also, in view of the fact that measurements are taken more or less at random and probably are not as frequent as irregularities, it seems that minor features of the distribution which the available observations cannot be expected to outline, should be entirely neglected. What is possible seems to be the representation of the general features, with elimination of the differences from this average condition which are peculiar to the individual station. This difference from average conditions is the anomaly which is considered in this discussion

If the isogonic lines are to express the average condition, there is needed a mathematical definition of the average condition. It may be taken to be the mean of a certain number of observations, in which case the differences from the mean will satisfy the requirement usual in adjustments of any kind, namely, that the sum of the residuals shall be zero. If, then, this mean value of the declination is taken to correspond to the mean position of the observations, the method of computation does not sacrifice anything to empirical ideas of form, preserves general features, and provides the cartographer with a comparatively smooth and uniformly changing series of values between which to interpolate isogonic lines.

In making isogonic charts of the states of the United States which have been listed in Table 1, the number of observations to be handled was not so great but what this amount of computational work could be spent on them. The general method was to substitute for each observation the mean value of it and the five nearest observations. Consideration of the size of the probable anomaly shows that a mean of six observations will eliminate all but a few minutes of station-anomaly. After the computation and plotting of the means on a working drawing, the isogonic lines were interpolated between them, and some free-hand smoothing of the lines was done to eliminate features of the distribution still present which did not seem to be general. The distribution of the declination as indicated by these smoothed lines has been taken as the average condition, and the difference between observation and chart-value at a given station has been taken as the anomaly of that station.

The first aim in computing these differences between observed and chart-values was to test the balance of the chart. For the chart as a whole, or for any considerable portion of it, the sum of the differences should be zero. In addition the differences or anomalies were classified according to size. From this classification it was apparent that small anomalies were more numerous than large ones, and that the number in a group decreased as the average size of the anomalies in the group increased. Furthermore, when

TABLE 1—*Occurrence of declination-anomalies for seven states of the United States*

Group	Ark.	Calif.	Fla.	Mo.	N. C.	Nev.	Tex.	Totals
Up to −106′	3	4	0	3	0	2	0	12
−105′ to − 96′	0	1	0	0	0	0	0	1
− 95 − 86	0	2	0	0	0	0	0	2
− 85 − 76	0	0	0	1	0	1	0	2
− 75 − 66	1	2	0	0	3	2	1	9
− 65 − 56	0	1	0	1	3	1	0	6
− 55 − 46	2	2	0	4	3	3	2	16
− 45 − 36	1	6	1	9	8	2	0	27
− 35 − 26	0	16	0	11	15	5	4	51
− 25 − 16	7	17	6	39	25	8	18	120
− 15 − 6	17	39	26	54	42	28	57	263
− 5 + 4	37	122	43	60	50	43	99	454
+ 5 + 14	24	42	33	38	40	36	66	279
+ 15 + 24	12	11	11	26	24	18	16	118
+ 25 + 34	2	7	6	10	12	9	8	54
+ 35 + 44	1	4	2	8	6	3	2	26
+ 45 + 54	0	3	0	0	7	2	2	14
+ 55 + 64	1	0	0	4	2	3	0	10
+ 65 + 74	1	2	0	1	4	2	1	11
+ 75 + 84	0	2	0	0	2	1	0	5
+ 85 + 94	0	1	0	1	0	0	0	2
+ 95 +104	0	0	0	2	0	1	0	3
+105 and up	2	1	0	4	6	3	0	16
Totals..........	111	285	128	276	252	173	276	1501

a curve was constructed with the number of anomalies in a given group as ordinate, and the average anomaly of the group as abscissa, it was apparent that the curve had the general form of the probability-curve.

This general form will be apparent from an inspection of Table 1, which is a tabulation of these anomalies separated into groups of equal range. The seven states are listed separately, and there is a total for all of them. When the data for any individual case are plotted in the manner described above, the resulting graph will have the general appearance of a probability-curve. Some of the lack of symmetry with respect to the axis of ordinates can be ascribed to lack of balance in the chart when the residuals were computed. This lack of balance is nearly all eliminated in the curve for the total, which is also a smoother curve than any of the others, as might be expected from the larger number of anomalies used.

A more definite assurance of agreement between observational data and theoretical curve can be had by fitting a curve of the prescribed form to the observational data, by a least-square computation of the constants h and k, and noting the discrepancies. This theoretical curve has been computed from the data for the state of Texas, and drawn in Figure 1. The small circles of the figure represent the observational data used in the construction of the curve, and the closeness with which they fall on the curve is a measure of the correspondence of the observational data to the

theoretical law. The agreement seems close enough to warrant the statement that the distribution is according to the law of occurrence of error.

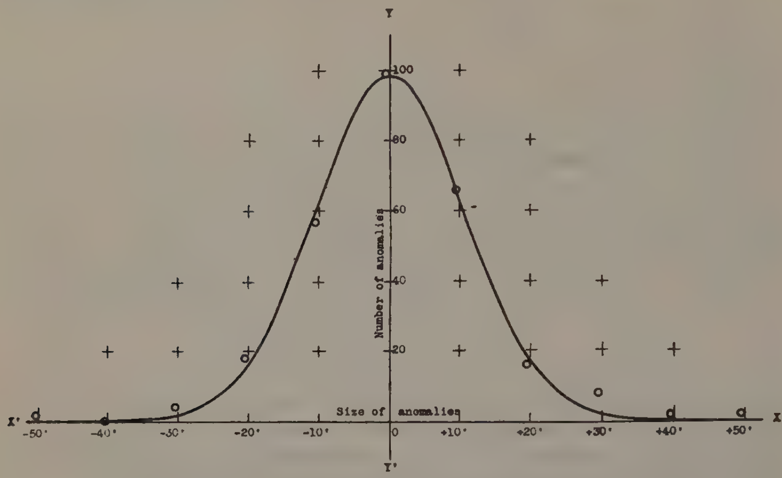


FIG. 1—Occurrence of declination-anomalies from data for Texas

The occurrence of anomalies in this manner permits the computation of a probable anomaly. This is computed from the usual formula for probable error

$$r=0.6745\sqrt{\Sigma v^2/(n-1)}$$

in which Σv^2 is the sum of the squares of the anomalies, and n the number of anomalies used in the computation. This probable anomaly is a measure of the closeness with which one may expect to estimate from an isogonic chart the value of the declination at any point where there is no observation.

Experience shows that the size of the probable anomaly will vary with the region. For the seven states of the United States included in Table 1 it varied from 9 minutes in Florida and Texas to 21 minutes in North Carolina. However, in the latter state, there were more large anomalies than there should have been, and in other respects the distribution of the observed anomalies was in poorer agreement with the law than was the case in the other states. The known occurrence of magnetite at numerous points was probably responsible for the large anomalies, and may have upset the theoretical distribution for the number of observations available. Judging from the groups considered here, and as a general proposition, the probable error in the estimation of the value of the magnetic declination from one of these charts should not be more than 15 minutes. This, of course, does not preclude larger errors, but merely states the probable error in a large number of estimations.

UNITED STATES COAST AND GEODETIC SURVEY,
Washington, D. C.

THE LAG BETWEEN SOLAR ACTIVITY AND MAGNETIC ACTIVITY

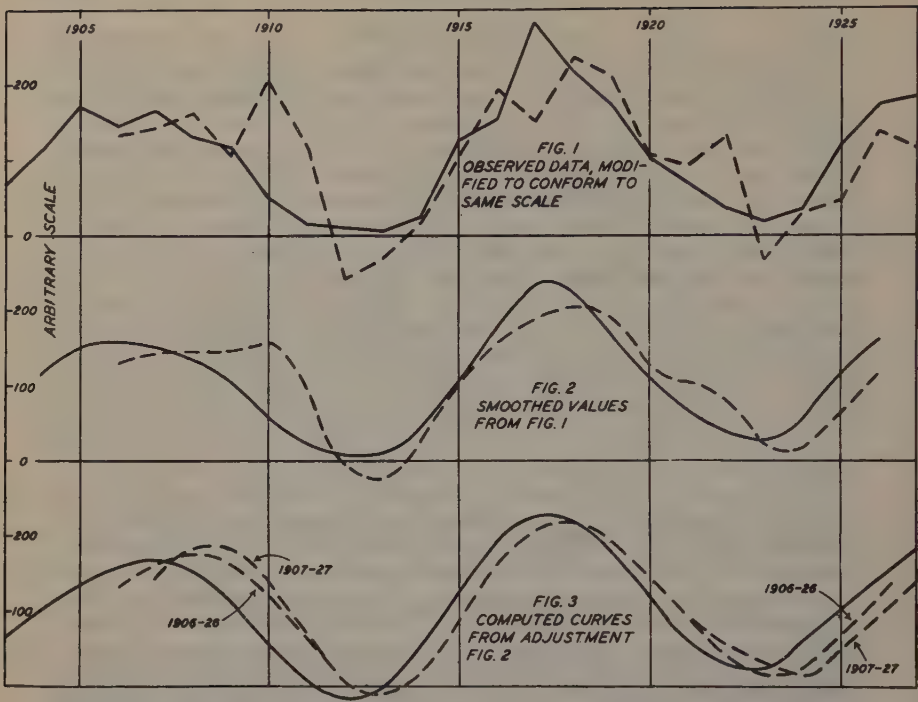
By H. W. Fisk

The question of an *immediate* connection between the existence of sunspots and magnetic disturbance on the Earth has been studied by many investigators, among them the late Dr. Charles Chree, who presents his conclusions in his "Studies in Terrestrial Magnetism" (Macmillan and Co., London, 1912). In this he affirms his earlier conclusion that an immediate connection is not shown by the facts, and says: "The conclusion which I drew in 1908 from these facts was that unless a time-lag exceeding one month be allowed, there must be agencies not associated with sunspots which powerfully affect the range of the magnetic needle." He further states (*loc. cit.*, p. 201) that such evidence as there is of a relationship between sunspot-area and absolute magnetic range on individual days favors the view that the phenomenon on Earth is influenced by the state of the Sun some days previous to the day considered, rather than the view that the terrestrial effect occurs simultaneously with the appearance of sunspots.

In discussing the Earth's magnetism and solar activity in 1918 (*Terr. Mag.*, v. 23, p. 66), L. A. Bauer says: "The pronounced lag in the magnetic curves with respect to the sunspot-maximum of 1905 and 1907 is also shown by the so-called international magnetic character-numbers. There is comparatively little lag, however, in all the curves, with respect to the period of minimum solar activity as shown both by sunspot-numbers and solar-constant values. Thus we are led once more to the suggestion that the lag in magnetic effect is a variable quantity and appears to depend on the degree of solar activity." The graph by means of which Bauer illustrated the argument just quoted made use of character-numbers only from 1906 to 1916, as no others were then available. The longer series now at hand shows the lag pointed out by both Chree and Bauer, but the supposition that this lag was excessive at times of sunspot-maxima is not confirmed at the maximum of 1917. The mean annual magnetic character-numbers are available for twenty-two years, namely, from 1906 to 1927, inclusive. The relative sunspot-numbers of course have been compiled for a much longer period. In order to make a direct graphical comparison between these two series of numbers they should be reduced for convenience to approximately the same numerical range. The sunspot-numbers vary between one and 104 for these twenty-two years, while the magnetic character-numbers are fractional and have approximately 0.45 and 0.75 for their lower and upper limits, respectively. A suitable formula for modification was found to be

$$2.7\,R=(C-0.515)\,10^3$$

in which C is the magnetic character-number and R the relative sunspot-number for the same year. The quantities thus modified and called for convenience C' and R', are plotted in Figure 1.



FIGS. 1-3—Graphs comparing mean annual values of solar activity and of magnetic activity by relative sunspot-numbers (solid lines) and mean magnetic character-numbers (broken-lines)

Aside from the general conformity of these two graphs, two features are worthy of attention. The character-numbers for 1910 and 1911 are unusually high as compared with the general trend of the curve and with the sunspot-numbers for those years. It was in this feature that Bauer found confirmation of his supposition that the lag at time of maximum was much greater than at time of minimum. The other feature to notice is the persistent lag of C' behind R'.

The general relation between these curves is better seen if some of the irregularities are smoothed out. Figure 2 shows the quantities after smoothing by the ordinary method of combining each value with the mean of the immediately preceding and following values. The sunspot-curve becomes reasonably regular, after smoothing, but the character-number curve much less so, though the lag is distinctly obvious. Except for the large character-numbers in 1910 and 1911, the curves are approximately parallel.

In comparing graphs of this kind the temptation is great to resort to some form of mathematical treatment by which the most probable smoothed curve would be derived. Such a treatment might be regarded as an attempt to force regularity upon

quantities essentially irregular, but there may be sufficient justification for the attempt. Counting sunspots or measuring sunspot-areas, and estimating magnetic character by the relative smoothness of magnetograms, are at best arbitrary and unsatisfactory methods of obtaining numerical measures of solar activity and magnetic activity on the Earth, two phenomena unquestionably closely related to some common phenomenon in a manner at present not understood. In discussing an apparent annual periodicity in sunspottedness, Bauer says:[1] "There is thus given, seemingly, support to the results of others with regard to a possible Earth-effect on various solar phenomena and to the view of possible planetary influence in general." A theory has recently been advanced by Franz Göschl[2] which supposes the outbursts of solar activity to be excited by the varying amounts of interplanetary matter drawn into the Sun under the accelerating and retarding influences of the planets in succeeding conjunctions and oppositions. From a supposition such as this, that these two related phenomena are in some way dependent upon the rhythmic orbital motions of the planets, it is easy to pass to the assumption that both solar activity and the Earth's magnetic activity vary with rhythmic regularity, and may be logically represented by a periodic curve. The irregular form of the curves drawn from observed sunspot- and character-numbers may well be regarded as the effect of our imperfect methods of measurement.

With this for justification, and using modified form of Fourier series, expressions were found that fitted the character-numbers from 1906 to 1926 and also the relative sunspot-numbers from 1903 to 1927. The longer series for the sunspot-numbers was adopted in order to smooth out the effect on the general trend of the curve which would have resulted from the unusual double maximum shown for 1905 and 1907, had the series begun with 1906. The resulting curves are plotted in Figure 3. Because of the inconvenience of breaking up the 21-year period between 1906 and 1927 in the Fourier analysis, the 20-year period from 1907 to 1927 was used, and to test its correctness the 20-year period from 1906 to 1926 was also analyzed. The agreement was very close except at the ends of the period, where the difference is shown by two sets of broken lines.

The evidence presented by these curves may not be such as to prove the existence of a lag of the magnetic effect behind the appearance of sunspots by a half-year or more, but it is strongly suggestive. The persistence of the phenomenon can scarcely be considered as accidental, especially when it is remembered that the quantities themselves are the results of measurements and estimates made by a large number of observers carried on for a long period of time. It will be of interest to observe how the

[1] *Terr. Mag.*, v. 26, 1921 (65).

[2] *Ann. Hydrogr.*, Aug., 1927, and Aug., 1928; *Met. Zs.*, Apr., 1928; *Terr. Mag.*, v. 33, 1928 (211-221).

numbers maintain this relationship through the present period of sunspot-maximum.

Table 1—*Comparison of relative sunspot and magnetic character-numbers*

Year	Relative sunspot-numbers						Magnetic character-numbers						Diff en
	Obs'd	Mod.	Computed			Resid.	Obs'd	Mod.	Sm.	Computed		Resid.	
	R	R'	(R')	R'_c	R_c	$(O\text{-}C)$	C	C'	(C')	C'_c	C_c	$(O\text{-}C)$	$(R'_c$-
1903	24.4	66	...	66	24.4	0	....	...	...	...	....	......	...
1904	42.0	113	116	103	38.1	+ 3.9	....	...	...	...	....	......	...
1905	63.5	171	150	136	50.3	+13.2	....	...	...	...	....	......	...
1906	53.8	145	157	162	60.0	− 6.2	.646	131	...	...	....	......	...
1907	62.0	167	152	169	62.6	− 0.6	.658	143	145	143	.658	.000	+2
1908	48.5	131	137	153	56.6	− 8.1	.678	163	144	179	.694	−.016	−2
1909	43.9	119	105	112	41.4	+ 2.5	.620	105	145	181	.696	−.076	−6
1910	18.6	50	58	57	21.1	− 2.5	.723	208	160	137	.652	+.071	−8
1911	5.7	15	22	7	2.6	+ 3.1	.634	119	96	66	.581	+.053	−4
1912	3.6	10	10	−16	−5.9	+ 9.5	.455	−60	− 8	3	.518	−.063	−1
1913	1.4	4	11	0	0	+ 1.4	.485	−30	−25	−7	.508	−.023	+
1914	9.6	26	46	53	19.6	−10.2	.535	20	29	17	.532	+.003	+3
1915	47.4	128	109	126	46.6	+ 0.8	.620	105	106	87	.602	+.018	+3
1916	57.1	154	179	193	71.4	−14.3	.708	193	160	161	.676	+.032	+3
1917	103.9	281	234	228	84.4	+19.5	.666	151	183	208	.723	−.057	+2
1918	80.6	218	222	220	81.4	− 0.8	.751	236	208	216	.731	+.020	+
1919	63.6	172	166	176	65.1	− 1.5	.726	211	191	190	.705	+.021	−1
1920	37.6	102	112	115	42.6	− 5.0	.620	105	128	143	.658	−.038	−2
1921	26.1	70	70	61	22.6	+ 3.5	.608	93	105	95	.610	−.002	−3
1922	14.2	38	40	32	11.8	+ 2.4	.645	130	80	56	.571	+.074	−2
1923	5.8	16	29	23	8.5	− 2.7	.483	−32	24	34	.549	−.066	−1
1924	16.7	45	56	61	22.6	− 5.9	.545	30	19	13	.528	+.017	+4
1925	44.3	120	114	101	37.4	+ 6.9	.562	47	65	52	.567	−.005	+4
1926	63.9	173	163	144	53.3	+10.6	.652	137	109	92	.607	+.045	+5
1927	69.0	186	...	186	69.0	0	.630	115	...	143	.658	−.028	+4

The numbers involved in these comparisons are given in the accompanying table, the headings of which have the following significance: R and C, the observed sunspot-numbers and magnetic character-numbers, respectively; R' and C', the same reduced to comparable magnitudes as explained in the preceding paragraphs; (R') and (C'), the results of smoothing; R_c' and C_c' indicate the results obtained from the computation of the smoothed curves from Fourier series (the values of C_c are computed for the years 1907 to 1927; those for 1906 to 1926 differ slightly); R_c and C_c, the computed values referred back to magnitudes of the originally observed quantities, from which they are subtracted to give the residuals in the columns headed $(O-C)$. Finally, the difference between the computed sunspot and character-numbers (modified) is taken, from which the regular change of sign in passing through a maximum or minimum is shown.

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SUMMARY OF THE YEAR'S WORK, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON[1]

By J. A. Fleming

The preparations for and the initiation of the seventh cruise of the *Carnegie* have made large demands upon the energy, initiative, and interest of the entire personnel. The vessel left Washington on this three-year cruise May 1, 1928, as planned. At the end of the year June 30, 1928, excellent progress had been made, which, despite the ambitious program undertaken in magnetic, electric, oceanographic, and meteorological observations, gives good promise of worth-while results in all these fields. An inspiring feature of the preparations has been the generous cooperation extended by interested investigators and organizations everywhere.

Progress was made in the application of electromagnetic methods for magnetic determinations on board. The results obtained so far during Cruise VII indicate entire success for the determination of inclination by the marine earth-inductor. The application of the inductor to the determinations of intensity is not yet solved. Provision having been made to drive the coil by a constant-speed, tuning-fork-controlled motor, the determination of intensity requires (1) determination of resistance of circuit, (2) means to read with sufficient accuracy a milliammeter, (3) maintenance of proper position of the rotating coil with respect to the Earth's field in spite of the motion of the ship, and (4) knowledge of dimensions of coil. Special circuit-connections with a testing-set provide means for rapid determinations of resistance during observation. To meet (2) a large inductance of two coils mounted on opposite legs of a closed magnetic core of "hypernik" was designed for connection in series to smooth out fluctuations in the current. For (3) the attempt is being made to attain the required stability gyroscopically, the instrument being mounted on the frame of a non-magnetic gyrostat-swing on the double reversible gimbal-system, used on previous cruises of the *Carnegie*, and driven through a universal joint and gears from the same constant-speed shaft that is used to drive the inductor coil. Experimental work on this application is being continued on board the vessel. Meanwhile intensity-determinations are made also by use of the C.I.W. deflector. The other standard magnetic instrument is the C.I.W. marine collimating-compass, the efficiency and precision of which were evidenced in earlier cruises.

Experiments were made with an especially designed compass, with a view to differentiate between the deviations caused by ship's motion by tilting and those caused by the non-coincidence of the center of mass and the point of suspension. The mathematical problem of tilting deviations was studied and applied to the experimental results.

The atmospheric-electric equipment for the *Carnegie* has re-

[1] Extracted from the annual report in Year Book No. 27 of the Carnegie Institution of Washington for the year July 1, 1927, to June 30, 1928, to which reference should be made for more detailed account of field, observatory, instrumental, and laboratory work.

ceived careful study and has been improved in many details. The electrograph uses an ionium collector for continuous photographic registrations of atmospheric potential-gradient, which is controlled by the eye-reading apparatus used on previous cruises, and improved conductivity-apparatus. The new equipment also includes an Aitken dust-counter with which observations are to be made regularly on board to obtain data for correlative studies with atmospheric electricity and possibly to determine a standard dust-count for unpolluted air.

The electrical salinity-apparatus after the design by Wenner of the United States Bureau of Standards was devised and constructed in the instrument-shop and found quite satisfactory upon test; the results already obtained on board fully justify its application in oceanographic studies.

The demands of the *Carnegie*, however, have not prohibited good progress in our other activities. The developments in the investigatory work have continued along lines as planned in previous reports in the compilation and study of accumulated data on the correlation between solar and terrestrial phenomena, on the laws governing diurnal, annual, and secular changes and space-distribution in terrestrial magnetism and electricity, on the definition of truly representative measures of magnetic and electric activity really interpretable from the laboratory point of view to permit analyses of the irregular phenomena and disturbances.

The problem of finding a suitable correction to be applied to the results of field-observations for each of the three magnetic elements, in order to eliminate the effects of hour-to-hour and day-to-day inequalities, has been given considerable attention. Observations in the field for diurnal variation, which have been regularly made for several years, have been found very useful. The feasibility of using the variations recorded at an observatory at a distance from the field-station, in the solution of this problem, was examined by comparing those records with variations actually determined in the field, and by comparing records at different observatories for the same day with each other. The collection and preparation for use of the magnetic data available for a general review of the rates of secular variation of each of the magnetic elements at the present time has also received attention.

The investigations of correlations of terrestrial magnetism and electricity and of solar activity with radio-reception conditions are of increasing significance. In this field the improvements made in the procedure for measuring effective heights of the Kennelly-Heaviside layer are important. The transmission consists now of very short pulses separated by relatively long intervals. The duration of each pulse is of the order of one six-thousandth second, successive pulses being separated by about one two-hundredth second, with occasionally longer intervals. Interference between the ground-wave and its reflection is now completely eliminated and quite unambiguous results as to height have been obtained.

The high-voltage work begun last year was continued. With

the means available a voltage of 5,200,000 volts was obtained. The ultimate limitation with the method used was due to the breakdown of insulation between turns of the Tesla coil. Higher potentials can doubtless be reached as soon as this is necessary by a proper modification in the coil-construction. Meanwhile the means already developed have been used for work with vacuum-tubes. A potential of 1,000,000 volts has been applied to a vacuum-tube. The ultimate purpose of the work being the production of high-speed electrical particles, a method of accelerating electrons to a speed corresponding to about 1,500,000 or perhaps 2,000,000 volts has been developed.

Practically uninterrupted records of the magnetic elements and of the atmospheric potential-gradient and positive and negative conductivity were obtained throughout the year at the Watheroo and Huancayo magnetic observatories and of potential gradient and negative conductivity at the observatory on the deck of the laboratory at Washington.

Records of earth-currents were obtained at Watheroo and Huancayo, with only slight interruptions during the year. A new electrode-system was installed at Watheroo with a view to eliminating certain disturbing factors. The precision now obtained appears to be such that with a few years' additional records, detailed quantitative comparisons with associated phenomena will be justified.

Increasing interest in the methods developed in the Department for earth-resistivity surveys has been manifested, especially with a view to its use in the location of minerals hidden in the Earth's crust. Surveys were made in the Michigan copper country during the summer of 1927, in cooperation with the Michigan College of Mining and Technology, to obtain further checks on the interpretation and to extend our knowledge of the resistivity of Earth materials.

Improvements in instrument design particularly for atmospheric-electric observations have been made as the result of laboratory experiments. These improvements make possible more rapid observation and more accurate results, particularly in the apparatus for measuring conductivity, ionic content, and penetrating radiation.

The activity of various governments and organizations in our fields has continued the marked increase reported last year. We have used every opportunity through instruction and loan of apparatus to encourage this and have effected additional co-operative arrangements both for magnetic and electric work. It is hoped that these may be increased in such number as to insure the continuity of secular-variation material and to offset the necessary curtailment in our field-operations to concentrate upon theoretical discussions and laboratory attack.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D. C.

PRELIMINARY NOTE ON THE ORIGIN OF THE PERMANENT MAGNETIC FIELDS OF THE SUN AND EARTH[1]

By Ross Gunn

The writer's studies of the effects produced by ions as they are caused to execute long free-paths and spiral about an impressed magnetic field by thermal agitation have led to interesting conclusions regarding the magnetic condition of the Sun and Earth. Such long free-path phenomena take place only in the rarified atmosphere of the bodies. A calculation of the currents flowing in the atmosphere of the Sun and Earth as a result of an observed radial inhomogeneity in the magnetic field shows that the currents are inadequate to account for the observed magnetic moments, even though they flow in the correct direction.

A further study of the effects produced by ions moving under thermal agitation in a magnetic field and executing short free-paths has led to a group of phenomena which are of great interest in the problem of the origin of the magnetic fields of the Sun and Earth. Ion-drifts which can give rise to currents have been found to result under the following conditions: (*a*) When a magnetic gradient exists which has a component perpendicular to the impressed magnetic field; (*b*) when an electric or gravitational field exists which has a component perpendicular to the impressed magnetic field. In each case the direction of the ion-drift is at right-angles to both the magnetic field and the gradient.

Under the solar and terrestrial conditions of approximate radial magnetic and temperature symmetry, drift-currents are set up which are in such a direction that magnetic regeneration can take place. A large magnetic field would then be expected to be built up from a very small "seed" field. The currents flowing in the steady state can be calculated from data which are approximately known, and the present theory leads to nearly the correct observed value for the magnetic moment of the Earth. The necessary data regarding the Sun are not yet available, but rough values indicate that the equatorial magnetic field is somewhat larger than that indicated by the extrapolation of diamagnetic data, namely, 12,000 gauss.

On the present theory the permanent magnetic fields arise from the thermal energy of the body, and the field would be maintained even if the bodies ceased their rotation. The fact that the Earth's magnetic field is distorted indicates that the interior temperature-distribution is not symmetrical about the geographic axis. This consideration lends support to the conclusion that the Earth was originally formed from the Sun by tidal or other forces, and indicates that the hemisphere now embraced by the Pacific Ocean was made up of very hot material from the deeper layers of the Sun.

A complete discussion of the new effects here described and their application to the Sun and Earth will be published shortly.

Naval Research Laboratory, *Washington, D. C., April 22, 1929*

[1] Published by permission of the Navy Department. This paper was presented in the symposium on physical theories of magnetic and electric phenomena, April 25, 1929, at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical U

A PRELIMINARY LIST OF ARCTIC MAGNETIC DETERMINATIONS

By Boris Weinberg

One of the chief aims of science is the economy of time for obtaining knowledge, and this circumstance justifies the efforts of those who are making summaries of experimental or observational results.

The usefulness of a summary depends, however, in a great degree on its completeness, because this quality only permits avoiding the difficulty of recurring to the original investigations and the still greater task of finding them. In the case of the magnetic determinations the attainment of completeness is close to an impossibility. Indeed, such observations are often found in books and articles the titles of which suggest no idea that they contain magnetic determinations. Thus, for example, "Observationes meteorologicæ factæ Petropoli annis MDCCLV. et MDCCLVI. St. V. et consectaria. Auctore I A. Brovn" (*Novi. Comm. Acad. Petrop.*, v. 7, 388-408, 1761) or "Extrait d'une lettre relativement à un tremblement de terre qui a eu lieu à Odessa le 14/26 novembre 1829, adressée au secrétaire perpetuel par M. Haüy, membre correspondant de l'Académie" (*Mém. Acad. St. Pétersb.*, v. 1 (VI sér.), Bull. Scient., 4-8, 1830).

Therefore in compiling now a catalogue of magnetic determinations in the arctic regions (according to the proposition of the second congress of "Aeroarctic") I would like to make an appeal to magneticians for help in securing complete references and data. For this purpose I give below a list showing the year and the author of all the arctic magnetic determinations which I have succeeded in finding. It is hoped that this in itself may be of interest as even such a list may facilitate finding references to other magnetic investigations.

In this list the designation "arctic regions" is conventionally defined as the part of the globe which is above latitude 65° north. When the name is in parentheses it indicates the person who computed or published the determinations. The year given is sometimes only the year of the beginning of the expedition concerned.

For those cases where the year is printed in italics the determinations are included either wholly or partly in the catalogue now being compiled by the Central Geophysical Observatory (see the note in *Terr. Mag.*, v. 33, 1928, p. 111) which relates to the territory of U. S. S. R. and of adjacent countries.

Such determinations are enumerated not only in order to give a list referring to all the arctic regions, but also in the hope that for the region between the meridians 25° and 195° east of Greenwich covered by this catalogue, indications may be received regarding results omitted in preparing this catalogue for publication and the manuscript of which is far more complete than its predecessors. For instance, Sabine's (*Phil. Trans.*, v. 162, 353-433, 1873) and Tillo's (*Repert. f. Meteor.*, v. 8, No. 2, pp. 82, 1881, and v. 9, No. 5, pp. 54, 1885) summaries contain only 55 per cent

and 53 per cent of all determinations which—for the same territory and the same interval of time—were available when these summaries were compiled. The catalogue now in press requires already an addition of nearly two per cent of its content; of these additional data about one-half are in some published papers which I had found only after the corresponding sheets were printed.

Communications regarding any unpublished results will be even more appreciated. Owing to the scarcity of determinations in the arctic (about 1,800 in the Soviet sector and over 1,500 in the other portion) every additional result will be of great value in making more reliable determination of the secular variation of the magnetic elements and in reducing the observed values to the epoch of the coming international arctic year.

Preliminary list of references to magnetic values in arctic regions

To 1599: *1556-7*, Borrough; 1587, Davis; *1592* (?) (Stevin); *1596*, Barents.

From 1600 to 1699: *1608*, Hudson; 1609, Poole; 1610-16, Baffin; *1611*, Logan; *1611*, May; *1614*, Gourdon; 1614, Fatherby; 1619, Remmertscz; *1676*, Wood.

From 1700 to 1799: *1728*, Behring; *1736*, Skurator and Sukhotin; *1736-40*, Dmitrij Laptev; *1737*, Ovtsyn; *1737*, Celsius; *1740*, Sterlegov; *1741*, Khariton Laptev; 1742-57, Claessen; 1747, Smith and Moore; *1748-77*, Hellant; *1757*, Beljaev; *1761*, Shelaurov; *1762-6*, Holm; *1765*, Chichagov; *1768*, Rozmyslov; *1769*, Bayly; *1769*, Mallet; *1769*, Pictet; *1769*, Rumovsky; 1771-2, Verdun; 1773, Phipps; *1775*, Bützow; 1776, Pickersgill; *1778-9*, Cook; *1779*, Russian Navy; *1780*, "Silnyi"; 1786, Löwenörn; *1787-9*, Sarychev; *1787-91*, Billings; *1791*, Gilev; *1791*, Julin.

From 1800 to 1849: *1800*, Abrosimov; *1800*, Ivanov; *1805*, (Gamaleja); 1805, Korobka; *1809-10*, Hedenstrom; 1815-17, Scoresby; *1816*, Christie; *1816-18*, Kotzebue; 1818, Fisher; 1818-20, Parry, Beechey, Hooper, and Sabine; 1819-22, Franklin and Hood; *1820-23*, Wrangel and Anjou; *1821*, Kozmin; 1821, Parry and Fisher; *1821-4*, Lütke; 1822, Scoresby; 1822-3, Parry and Sabine; *1824*, Ragozin; 1824-5, Parry, Crozier, Foster, and Hooper; *1824-8*, Ivanov; *1824-32*, Reineke; 1825, Guédan; *1825*, Hansteen and Segelcke; *1825*, Meiländer and Paludon; 1825-7, Franklin, Back, Richardson, and Kendall; *1826*, Beechey, Belcher, and Wainwright; *1826*, Kharlov; *1826*, Berejhnykh and Pakhtusov; *1826*, Meiländer, Vibe, and Tönder; *1827*, Junker; *1827*, Keilhau; 1827, MacCormick; 1827, Parry; *1827-8*, Miljukov and Pakhtusov; *1828*, Lütke; *1828*, Reineke, Krotov, and Junker; *1828-9*, Erman; 1829, Graah; *1829*, Hansteen; *1829-30*, Krotov and Kazakov; 1829-33, Ross; *1832-5*, Pakhtusov; 1833, Blosseville; 1833-4, Back; 1834, Dutaillis; 1835, Trèhouart; *1835*, Fedorov; 1836, Ross; 1836-7, Back; 1837-9, Simpson; 1838, Boeck and Meyer; *1838*, Lottin and Bravais; *1839*, Moiseev; *1839*, Rogachev; *1839*, Ziwolka; *1840*, Afanasjev; 1840, De la Roche-Poncié; *1841*, Saveljev; *1843*, Middendorf; 1844, Lefroy; 1846, Liljehoek; *1846*, Kowalsky; 1846, Rae; *1847-9*, Käntz; *1847-9*, Kellett; 1848, Brown; 1848,

Richardson; 1848, Ross and Robinson; *1849*, Moore; 1849, Roe; 1849, Richardson; 1849, Robinson and Brown.

From 1850 to 1899: 1850, Kierulf; 1850, Krusenstern; 1850-1, MacClure; 1850-4, Maguire, *1851-4*, Collinson; 1851, Ommaney, Allen, Mecham, and Osborn; 1852, Inglefield; 1852, Kellett, Allen, and MacDougall; 1852, Kennedy; 1852-4, Belcher; 1853, Bellot; 1853, MacDougall; 1853-5, Kane; *1854*, Ommaney; 1854, (Warberg); *1855*, MacDougall; 1857, Allen; 1857, Blakiston; 1857, MacDougall; 1858, Collinson; 1858-9, MacClintock and Allen; *1860*, Arndtsen; *1860*, Russian Navy; 1860-1, Hayes, Sonntag, Radcliff, and MacCormick; *1860-1*, Zarubin; 1861, Chydenius; 1861, Dunèr; *1861*, Krusenstern; 1861-3, (Gratzl); 1865, Järnefest; 1865, Lenz; 1865, Morache; 1868, Koldewey; 1868, Lemström; 1869, Koldewey and Börgen; 1869, Raymond; *1870*, Maidel; *1870*, Tader; *1870-1*, Belavenets; 1871, Forsman; *1871*, Melsom; 1871-2, Bryan, Hall, and Meyer; 1873, Wijkander; 1873-4, Weyprecht, Brosch, and Orel; 1874, Carlsen; 1875, Koolemann; *1875*, Müller; 1875-6, (Creak); *1876*, Dahl; *1876*, Onatsevich; *1876*, "Vsadnik"; *1876-7*, Moore; *1877-8*, J. N. Smirnov; *1878*, Wille; *1878-9*, Hovgaard; 1878-9, Speelman and Beijnen; 1879, De Long; 1879-83, Steenstrup and Kammer; *1880*, Dall and Baker; 1880, (Freeden); *1880*, Lamie and Calmeijer; 1880, Sherham; *1880-1*, Hooper; *1881*, Berry and Putnam; *1881*, "Corwin"; *1881*, Lamie and Booj; 1881, U. S. Revenue Marine; 1881-3, Greely, Israel, Lockwood, and Rainard; 1882, Strelok; 1882-3, (Borger and Neumayer), (Solander), (Steen); *1882-3*, Andreev; *1882-4*, Lemström and Biese; *1882-4*, Jurgens; *1882-92*, Vilkitskij; *1883*, Eigner; *1883*, Snellen; 1884, Crossby; 1884, Ray; 1884, Sebree; *1887*, H. F. Abels; *1887*, Russian Navy; 1888, Ogilvie; *1889*, Astafjev; *1889*, Prestin; 1889, Stockton; 1890, Edmonds; *1890*, Kulikov; 1890, Turner; 1890-900, "Active," "Calipso," "Ruby," etc.; 1891, MacGrath; 1891-2, Ryder; 1891-3, Stade; 1891-5, Jhdanko; 1892, Blanpré and Corfort; *1893*, Shilejko; *1893*, Tsim and Semenov; *1893-5*, Scott-Hansen; 1894, French; *1894-901*, Vilkitskij, Brovtsyn, Ivanov, Kryjhanovskij, Mordovin, Stepanov, and Janov; *1895-902*, (Geelmuyden); *1896*, Bukhteev; *1896*, Golitsyn; 1896, Putnam; 1896, Sikora; 1897, Petersen; *1897*, Russian Navy; *1898*, H. F. Abels; 1898, Amdrup; 1898, Carlheim-Gyllenskiöld; 1898, Hamberg; 1898, Schwerer; 1899, Ostoshchenko-Kudrjavtsev; 1899, Solander; *1899-900*, Cagni.

From 1900 to 1927: 1900, Bauendahl; 1900, Deploranskij; 1900, Pratt; *1900-1*, Seeberg and Kolchak; 1900-2, Peary; 1900-3, U. S. Geol. Survey; *1901*, Alenius; *1901*, Kolomeitsov; *1902*, Brovtsyn and Janov; *1902*, Steen; *1903*, Bukhteev; *1903*, Matisen; *1903-4*, Peters, Porter, and Tafel; *1903-4*, Drijhenko; *1904*, Armitage; *1905*, Baklund; *1905*, (Herrmann); 1905-7, Harrison; 1906, Peary; *1906-7*, Wegener; *1906*, Russian Navy; 1906, U. S. E.; *1907*, Bukhteev; *1907*, Rachlew; 1908, Craft; *1908*, Russian Navy; *1908*, D. A. Smirnov; *1908*, Stelling; 1908, U. S. Coast and Geodetic Survey; *1909*, Skvortsov; *1909*, Weber; 1910, Bukhteev; 1910, Filchner; *1910*, Hintikka; *1910*, Maksimov; *1910*, Russian Navy; 1910, U. S. Coast and Geodetic Survey; *1910-12*, Sodankylä

Observatory; *1911-12*, Sakharov; *1911-16*, Matusevich; 1912, Mercanton and de Quervain; *1912*, Neelov; *1912*, Neupokoev; *1912*, Weinberg and Dudetskij; *1912-22*, Keränen; *1913*, Nikolskij; *1913*, Sedov; *1913-5*, Väisälä; *1914*, "Carnegie"; 1914, Ljungdall; *1914*, Wiese; *1915*, Dombrovskij; *1915*, Voznesenskij; 1915-17, Stefansson; *1916*, R. H. Abels; *1916*, Bonchkovskij; 1918, U. S. Coast and Geodetic Survey; *1918-21*, Amundsen; *1918-24*, Rose; *1919*, Heiskanen; *1919*, Shubin; *1919*, Urvantsev; *1920*, Russian Navy; *1920*, Timofeevskij; *1920*, Weinberg; *1921*, Bonchkovskij; *1921*, Evgenov and Khmyznikov; *1921*, Jhongolovich; 1921, Ljungdahl; *1921*, Russian Navy; 1921-2, Howell; 1922, Sverdrup; *1922-4*, "Maud"; *1923*, Pavlov; *1923-7*, Matochkin Shar Observatory; *1924*, Belobrov; *1924*, Ivanovskij; *1924*, Russian Navy; *1924-7*, Jhongolovich; *1924-7*, Novopashennyj; *1925*, Gusev; *1926*, Nezdjurov; *1927*, Krakan and Mytarev; *1927*, Malkin.

Leningrad, U. S. S. R.,
May 10, 1928

LETTERS TO EDITOR

PROVISIONAL SUNSPOT-NUMBERS FOR JANUARY TO MARCH, 1929

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	January	February	March	Day	January	February	March
1	..[b]	34	44[ad]	17	..[b]	56	40
2	..	38	47	18	89	54	24
3	64	32	*W*59[c]	19	77	*W*32[c]	19
4	66	44	..[d]	20	92	56	15
5	45	46	53	21	77[b]	58[a]	11[b]
6	*E*39[c]	74[a]	73	22	65	58	..
7	61	..	74	23	102	57	*E* ?[c]
8	73[a]	91	90[b]	24	..[a]	65	..
9	80	117[a]	103	25	51?	60	22
10	74[a]	121[b]	91[b]	26	..[b]	..	35
11	44	..[b]	*E*92[bc]	27	55	69[a]	39
12	*M*82[c]	83[a]	94	28	20	52	18[a]
13	82[a]	70	77	29	22	..	*W*20[c]
14	90[a]	..	66	30	*M*29[c]	..	40
15	77	68	*W*65[adc]	31	31[a]	..	55[d]
16	113	51	58				
				Means	65.4	61.9	52.8
				No. days	26	24	27

Mean, January to March 1929: 60.0 (77 days)

[a] Passage of an average-sized group through the central meridian.

[b] Passage of a larger group through the central meridian.

[c] New formation of a larger or average-sized center-of-spot activity: *E*, on the eastern part of the Sun's disc; *W* on the western part; *M* near the central meridian.

Zürich, Switzerland W. Brunner

NOTES ON AURORA IN NEW ZEALAND

The Reverend Alexander Don, of Ophir, Central Otago, a keen observer, has communicated to the Meteorological Office of New Zealand the following notes on auroral displays, the times indicated being New Zealand standard time, which is $11^h\ 30^m$ ahead of Greenwich: March 26, 1928, faint aurora at $22^h\ 00^m$; April 16, 1928, faint aurora at $22^h\ 30^m$; August 29, 1928, faint aurora at $19^h\ 30^m$ to $20^h\ 30^m$.

EDWARD KIDSON

Meteorological Office, Wellington, New Zealand, February 7, 1929

PRINCIPAL MAGNETIC STORMS

CHELTENHAM MAGNETIC OBSERVATORY
JANUARY TO MARCH, 1929[1]

[1] Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

(*Latitude 38° 44′.0 N.; longitude 76° 50′.5 or $5^h\ 07^m.4$ W. of Gr.*)

Greenwich mean time						Range		
Beginning			Ending			Dec'l	Hor. int.	Ver. int.
1929	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Feb. 27	20	..	28	15	..	78.0	330	446
Mar. 11	13	54	13	01	..	62.8	270	321

GEO. HARTNELL, *Observer-in-Charge*

HUANCAYO MAGNETIC OBSERVATORY
NOVEMBER, 1928, TO FEBRUARY, 1929

(*Latitude 12° 02′.7 S.; longitude 75° 20′.4 or $5^h\ 01^m$ W. of Gr.*)

Greenwich mean time						Range		
Beginning			Ending			Dec'l	Hor. int.	Ver. int.
1928	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Nov. 10	6	55	10	19	30	7.5	217	27
Nov. 11	16	56	11	21	30	7.5	165	16
Nov. 17	14	51	17	18	30	2.5	190	8
1929								
Feb. 16	15	10	19	17	30	11	525	31
Feb. 26	19	21	28	18	..	10.5	490	28

November 10, 1928—A magnetic disturbance lasting only a few hours began at $6^h\ 55^m$, with an increase of 25γ in horizontal intensity, and was marked by having the minimum at $15^h\ 33^m$,

which is about the usual time for the daily maximum. The vertical-intensity trace showed practically no abrupt movements, but the declination trace was somewhat serrated during the height of the disturbance.

November 11, 1928—A short magnetic disturbance began at $16^h\ 56^m$, with a 10-γ decrease in horizontal intensity, followed immediately by an increase of 100γ in five minutes. The trace was greatly disturbed during the first two hours after the beginning and showed several large and rapid changes. Following this there was a period of lesser disturbance lasting over two hours, which might ordinarily have passed for less than a storm condition. The vertical-intensity and declination traces were somewhat serrated during the first two hours.

November 17, 1928—A short magnetic disturbance with an abrupt commencement began at $14^h\ 51^m$ with an increase of 125γ in horizontal intensity within 11 minutes. The vertical intensity and declination too gave slight increases at the same time After the first rapid increase, the horizontal-intensity trace showed a saw-tooth effect on several moderate peaks and bays, and the vertical intensity and declination showed small rapid fluctuations during the period of the disturbance, which ended rather suddenly after 21^h.

February 16-19, 1929—Beginning with only a moderate disturbance at $15^h\ 10^m$ on February 16 and continuing so during the night following. On February 17, beginning at about $12^h\ 10^m$, a much more active storm developed. The vertical intensity and declination showed marked variations for about six hours, and the horizontal-intensity trace had several large peaks and bays with a minimum at $16^h\ 03^m$. After 18^h this heavy disturbance diminished and until the end of the storm at 17^h on February 19 it was indicated only by somewhat abnormal variations in the vertical intensity and declination, and by very low horizontal intensities during the nights of the 17th and 18th and several marked decreases in horizontal intensity during the daily maximum on the 19th.

February 26-28, 1929—A magnetic storm began suddenly at $19^h\ 21^m$ with an 8-γ decrease in horizontal intensity and an immediate increase of 72γ in three minutes, and also a visible increase in vertical intensity and declination. The storm was characterized by subnormal horizontal intensities over a period of about two days, and by fluctuations in the horizontal intensity that were less rapid than are usually recorded at this Observatory during a storm. The minimum occurred in the evening of the 27th at $19^h\ 20^m$ instead of as usual at the time of the daily maximum. The vertical-intensity and declination traces showed moderate fluctuations at various times during the storm, corresponding usually with changes in the horizontal intensity. The storm ended rather abruptly during the daily maximum on the 28th.

All times given are Greenwich civil mean time.

Paul G. Ledig, *Observer-in-Charge*

Watheroo Magnetic Observatory

October to December, 1928

(Latitude 30° 19′.1 S.; longitude 115° 52′.6 or 7^h 44^m E. of Gr.)

October 18, 1928—This was a short-lived storm with sudden commencement at 7^h 25^m on October 18, and which ended in declination and vertical intensity at 23^h 04^m and in horizontal intensity at 23^h 03^m on the same day. The ranges were 34′.8 in declination, 287γ in horizontal intensity, and more than 203γ in vertical intensity.

Earthquake record, November 28, 1928.—A disturbance such as is usually attributed to earthquakes was recorded on the magnetogram of November 28. The features recorded were for declination, horizontal intensity, and vertical intensity, respectively. Times beginning—10^h 49^m, 10^h 48^m, 10^h 54^m; times ending—10^h 57^m, 10^h 57^m, 10^h 59^m; ranges in mm—1.1, 0.5, 1.2; waves recorded —*P* defined, *S* and *M* mingled; *P*, *S*, and *M* defined; *S* and *M* only.

REVIEWS AND ABSTRACTS

(See also pages 116 and 122)

Weida, F. M.: *On various conceptions of correlation.* Ann. Math. Princeton, N. J., v. 29, No. 3, July, 1928 (276-312).

This is a valuable paper to the statistician, actuary, and computer, and especially so to any one interested in the theoretical exposition of correlation. It is a comprehensive development of the subject, both historical and mathematical. It has all the advantages of a treatise in that it presents a structure built consistently on accepted foundations without the disadvantage of being compelled to go into details that might be tedious to all but a few. Besides, the treatise would generally confine itself to a single method of development, while the author of this paper sketches the three independent developments, namely: (1) That by the English school, based on the *theory of error* and led by Pearson; (2) that by the Italian school, based on the *theory of connection and concordance*, and led by Gini; and (3) that by the Russian school, based on the *a-priori theory of probability*, and led by Tschuprow. In addition, the author points out the relations between the different measures of correlation used by the various schools. For example, it is shown that Pearson's *correlation-ratio* is a measure of *connection* and that Pearson's *correlation-coefficient* may be considered a measure of *concordance*, The reader of this paper will be greatly aided by extremely copious references to the literature of the subject in treatises as well as in periodicals, and even the specialist will find himself indebted to Professor Weida.

C. R. Duvall

Gehlinsch, E.: *Ueber den Zusammenhang zwischen der Fleckentätigkeit auf der Sonne und den Störungen des erdmagnetischen Feldes.* Mitteilungen aus dem Institut für Theoretischen Astronomie und Analytische Mechanik in der Lettländischen Universität zu Riga, Nr. 3, Riga, 1928 (77-185).

The present paper sets forth results of a statistical study of the assumed connection between sunspot-activity and disturbances in the Earth's magnetic field. It differs, however, from previous investigations in that it is limited to cases when, for a certain time, only a single spot is visible on the photosphere. From the "Greenwich heliographic results" the author selects forty such individual spots from the two years of sunspot-minimum 1910-1911, and thirty from the two years of sunspot-maximum 1915-1916 thus making a total of seventy spots distributed over a period of four years. The characteristics of these spots are noted and their passage across the Sun's disc is compared with the corresponding traces of magnetic declination and horizontal intensity on the magnetograms of the Potsdam Magnetic Observatory. On the basis of these rather limited data, the author reaches the following conclusions: (1) The efficiency of sunspots in producing disturbances in the Earth's magnetic field depends to some extent on the surrounding faculæ—the more numerous the faculæ, the more efficient the spots. (2) Every spot retains its power of producing magnetic disturbances on its reappearance; the effectiveness, however, increases or decreases in accordance with the size of the spot and the presence of the accompanying faculæ. (3) The appearance of a spot on the solar disc is almost invariably attended with disturbances of the Earth's magnetic field; exceptions are rare, only two being found among the seventy cases examined. (4) Magnetic disturbances are observed independently of the position of the spot on the photosphere; there are, however, positions from which the spots seem to exert a greater or lesser effect. Maximum magnetic activity is found when the spot is on the eastern and minimum when it is on the western edge of the Sun. Owing to the scantiness of data, no definite conclusions regarding the central regions of the Sun could be reached.

The author holds that the connection between the sunspot-activity and magnetic disturbances on the Earth may be satisfactorily explained with the aid of the theory of electrically charged corpuscles emitted from the Sun. On the assumption that the particles reaching the Earth depart from the spot in general tangentially to the Sun's surface with an initial velocity of 1200 to 5000 km/sec, it is found that they leave the Sun at its eastern edge before the appearance of the spot and at the western edge only after its disappearance. The time required for the corpuscles to traverse the distance from the Sun to the Earth is from 0,5 to 1.5 days. The absence of maximum effectiveness at the western edge of the solar surface may therefore be regarded as a consequence of the temporal propagation of the effect. H. D. Harradon

Chree, C.: *The regular diurnal variation of magnetic declination at Kew Observatory from selected years of many and few sunspots, 1859-1894.* London, Met. Office, Geophys. Mem., No. 43, 1928 (33 with 1 pl.).

Magnetographs began recording at Kew Observatory in 1858 but there was no systematic tabulation of the magnetic curves until 1891. Uncertainties with respect to base-line values and temperature-corrections made it inexpedient to attempt the reduction of the intensity-components, but as that difficulty does not apply to the declination-curves which have a constant value throughout, this ele-

ment was chosen for investigation. The author had previously made a complete discussion of the Kew magnetic data for one sunspot-cycle, 1890-1900. The present paper supplements that discussion by considering the effects of many and few sunspots on the behavior of the diurnal variation of declination during the three preceding cycles. To reduce the amount of labor involved in measuring so many magnetograms, some of which were badly faded and others defective from other causes, two years were chosen at each sunspot-maximum and sunspot-minimum, a third year being included at the maximum of 1870 since the number for all three years was above 100 at that occurrence. There were therefore six years of few, and seven years of many sunspots. The years discussed were: 1859-1860, 1866-1867, 1870-1871-1872, 1878-1879, 1883-1884, and 1888-1889. For each of these 13 years there is a table giving the mean diurnal-inequality at each hour for each month, for the entire year, and for the winter, equinoctial, and summer seasons.

In summarizing the material from the tables the data for the three years at the sunspot-maximum of 1892-1893-1894, taken from the earlier discussion, were included to make the mean epoch of the group of years of many sunspots coincide with that of few sunspots. The hourly values of declination used were the instantaneous values at the exact hour of Greenwich mean time. The earlier practice was followed of drawing a smooth line through the magnetograms of disturbed days, and taking the values from the line. If the day were greatly disturbed it was rejected. The total number of days rejected for this and other reasons was 458 for the three years, the greatest number for any month being 9, and for any year, 58. The summary shows that the western elongation for each season in both groups of years, occurred at 13^h, with a slight indication of a secondary elongation (or maximum in the sense employed by the author) at 2^h, somewhat later in years of few than of many sunspots. The eastern elongation (minimum) when the year is considered as a whole falls at 8^h in both groups. The secondary minimum falls at 24^h in years of many sunspots, and at 22^h in years of few sunspots. When the separate seasons are considered there is greater irregularity. The most conspicuous difference between the two groups is in the range of diurnal inequality. This range in years of few sunspots is to that in years of many sunspots approximately as 2 to 3. The same approximate ratio applies when the average departure of diurnal inequality is considered.

The monthly mean value of the range in diurnal inequality is a minimum in December for both groups of years, though in four of the nine cases given the January mean is less than the December mean of the previous year, two of the four cases being in years of many and two in years of few sunspots. The maximum monthly mean diurnal range in years of many spots occurs in April though in two of the 10 years it falls in August and once in May. When plotted the curve shows two nearly equal maxima, in April and August, with a slight bay between. The curve for the six years of few spots shows a long flat maximum in which the June value is very slightly greater than for April and August. In both groups the curves show a steep descent to a narrow minimum in midwinter and an equally steep rise.

One of the chief possibilities kept in mind during the discussion was that of a gradual change in the diurnal inequality. It was found that in the seven years of many sunspots the western elongation occurred at 13^h in 68 of the 84 months, and at 14^h in the other 16 months. Apparently the occurrencies at the later hour

were more frequent at the end of the period than at the beginning, indicating a retardation of this feature of about five minutes in 30 years. The evidence from the years of few sunspots is less satisfying though a slight tendency for the maximum to get later can be seen. The question of a possible retardation was also attacked by means of harmonic analysis. The phase-angle for the various waves is obviously affected by sunspot-activity. The value of the phase-angle for the 24-hour wave was 9° 48′ less for the years of many than for years of few spots, indicating that the maximum so far as the predominating wave is concerned, came 39.2 minutes later in years of maximum sunspots than in years of minimum sunspots. The difference for the 8-hour wave was but 12.8 minutes and much less for the 12-hour and 6-hour waves. For the successive periods of sunspot-maximum there is a steady decrease in the phase-angle from 1859-1860 to 1892-1894. The evidence, however, is weakened somewhat when account is taken of the relative sunspot-numbers for these several periods. The evidence from the successive years of sunspot-minimum points in the same direction though with some irregularity. In explaining the significance of the progressive retardation of the time of western elongation, it is pointed out that such a retardation should be expected on account of the secular variation of declination. Between 1860 and 1893 the westerly declination diminished 4° 10′ to which corresponds a clockwise rotation of the radius-vector of the vector-diagram through an equal angle. This denotes a retardation of the time of maximum of 16.7 minutes, an amount comparable to that revealed by the discussion.

The data are further discussed by means of Wolf's formula $R=(a+bS)$ in which R is the magnetic range or other magnetic magnitude, S is the sunspot-number, and a and b are constants. When analyzed in this way, the summer season is conspicuously the period of greatest diurnal-inequality when S is zero. The constant b, however, is distinctly greatest during the equinoctial season so that in years of many sunspots the equinox becomes the season of largest amplitudes. When Wolf's formula is applied to the diurnal inequality for months, a is distinctly a minimum in midwinter, having also a secondary minimum in summer, flanked by decided maxima in the equinoctial months. The value of b has the same characteristics. H. W. Fisk

Maris, H. B., and E. O. Hulburt: *A theory of auroras and magnetic storms.* Phys. Rev., Menasha, Wis., v. 33, 1929 (412-431). [Author's summary preceding article.]

The physics of the atmosphere of the Earth under a quiet Sun is discussed in detail. The daytime temperatures above 100 km increase with the height to roughly 1000° K at a 400-km level; new tables of the molecular density of the atmosphere to great heights are given. In the region above 450 km, where the molecular free-paths are very long, a portion of the highly absorbed ultraviolet light of the Sun is converted into kinetic energy by processes of atomic excitation and ionic recombination, and produces 10^6 atoms cm^{-2} sec^{-1} which fly out from the Earth with velocities of 10 km sec^{-1} or more. The atoms attain levels of 30,000 to 50,000 km in three hours and are then ionized by the ultraviolet sunlight. The ion-pairs thus formed spiral about the lines of force of the Earth's magnetic field and a majority are guided to the polar latitudes. They fall into a zone roughly 25° from the magnetic poles and give rise to the auroras there; this is the observed zone of maximum auroral frequency. It takes the ions

nine hours to travel from the equator to the poles, and therefore the aurora occurs more often in the early hours of the night than in the later hours, as is observed. The fact that short wireless waves traverse polar regions supports the view that the ionization is due to the ion-influx from lower latitudes; for the sunlight is too weak to make many ions there. It is assumed that the Sun, when active, emits a sudden (1/2 hour) blast of ultraviolet light. For example, if 1/10,000 part of the solar surface, normally at a temperature of 6,000°, were removed and there were exposed the black-body radiations at 30,000°, the solar constant would be increased by one per cent and the ultraviolet energy, $\lambda 500$ to 1000Å, by 10^5. This ultraviolet energy, completely absorbed in the high-lying (200-km) atmospheric gaseous layers, blasts out these layers to produce ions up to 40,000km. Due to gravity and the Earth's magnetic field the first effect of the high-flying ions is to produce a sudden current, 10^6 amperes, in planes parallel to the equator, which causes a magnetic field 10^{-3} gauss simultaneously over the whole Earth, as is observed in the first phase of the world-wide magnetic storms. Numbers of ions descend to the zones 23° from the magnetic poles and form there diamagnetic concentrations of considerable intensity (also give rise to the auroras). On the assumption that the blast of ultraviolet light does not die away abruptly but continues with lessening intensity for a day or so, the diamagnetic concentrations wax with the day and wane with the night. The changes in the Earth's magnetic field caused by this diamagnetism are found to agree in nearly every detail with the observed complicated diurnal storm-variations in the three magnetic field-components at all latitudes.

NOTES

(See also page 142)

11. *American Geophysical Union*—The tenth annual meetings of the American Geophysical Union and its sections were held in Washington, D. C., April 25 and 26, 1929. The meetings were most successful and well attended. Among the papers of particular interest to the readers of the JOURNAL and some of which it is hoped will be printed in full or in abstract in future issues are the following: The corpuscular-ray theory of the aurora, by N. H. Heck; The ultraviolet theory of aurora and magnetic storms, by E. O. Hulburt; The atmospheric dynamo-theory of variations in earth-currents and terrestrial magnetism—a review, by O. H. Gish; A tentative theory of the permanent magnetic field of the Sun and Earth, by Ross Gunn; Echo-sounding of the Kennelly-Heaviside layer, by M. A. Tuve. All these papers were presented at the symposium on physical theories of magnetic and electric phenomena of the Section of Terrestrial Magnetism and Electricity. At the General Assembly held on April 26, W. J. Peters presented a paper entitled "The work of the *Carnegie* to date."

William Bowie and *L. H. Adams* were elected chairman and vice-chairman, respectively, of the whole Union for three years beginning July 1, 1929, *J. A. Fleming* continuing as general secretary. *N. H. Heck*, *L. W. Austin*, and *H. W. Fisk* were elected chairman, vice-chairman, and secretary, respectively, of the Section of Terrestrial Magnetism and Electricity for three years beginning July 1, 1929.

12. *Cruise VII of the Carnegie*—The *Carnegie* sailed from Apia, Western Samoa, April 20, for Guam where she arrived May 20 sailing May 25. The position of the vessel by radio advice May 1 was latitude 2°.5 north, longitude 165°.1 west. This date marked the first anniversary of the beginning of Cruise VII; during the first year the results obtained included: 350 magnetic declinations, 110 magnetic intensities and inclinations, 98 ocean-stations, 800 sonic depths, 225 atmospheric-electric stations, 90 balloon-flights, and 50 bottom-samples, besides daily and continuous records of air and water temperature, humidity, and pressure. On June 1 the position was latitude 28°.5 north in longitude 144°.2 east on the course to Yokohama. A new deep, which was named "Fleming Deep," was discovered May 29 (latitude 23°.8 north, longitude 144°.1 east) and was found to have a maximum depth of 8,650 meters (28,380 feet), thus being the sixth greatest ocean-depth known at present. The vessel arrived at Yokohama June 7, and will sail for San Francisco the last week in June.

13. *Aurora of February 28, 1929*—Professor Carl Störmer, Bygdö, Oslo, Norway, reports he observed on February 28, 1929, between 18^h and 23^h Greenwich mean time, an unusual aurora in the form of an isolated pulsating and defective arch. A long series of photographs of the aurora was obtained for the purpose of determining its height and position. Prof. Störmer states that only twice before has he observed similar displays, namely, on the evenings of March 23 and December 19, 1919. He would be pleased to receive reports on auroras seen on February 28, 1929, particularly from points in America or on the Atlantic Ocean.

14. *Geophysical methods of surveying*—This was the topic chosen for the "Meeting for the Discussion of Geophysical Subjects" held in the rooms of the Royal Astronomical Society, London, on February 15, 1929. The discussion was opened by A. Brougham Edge who dealt with the so-called "geo-electric" methods which he treated under three headings, namely, spontaneous polarization, equipotential, and electromagnetic methods. F. W. P. McLintock then gave an account of the work done by the Geological Survey with the Eötvos torsion-balance. W. H. Fordham and W. M. H. Greaves discussed magnetic surveying, the former advocating the use of portable variometers in view of the lack of accuracy of absolute observations.

15. *Erratum*—In third line of abstract of article by G. Hoffmann and F. Lindholm on page 261 of v. 33, 1928, of this JOURNAL, read "one to two per mille" instead of "one to two per cent."

16. *Removal of magnetic station at Buitenzorg, Java*—The magnetic station of the Royal Magnetical and Meteorological Observatory at Batavia has been removed to the Island of Kuiper (Quarantine Station, Bay of Batavia) on account of the proposed extension of the electric tram-lines to Buitenzorg in the immediate future. The geographic coordinates of the new station are: Latitude, 6° 02′ south; longitude, 106° 44′ east. The distance from the Batavia Observatory is 19.1 km. The station is equipped with the instruments previously used at Buitenzorg, and the same method of computation will be used as heretofore. Registrations were begun at the new station on November 1, 1928. Correspondence should be addressed to the Director, Royal Magnetical and Meteorological Observatory at Batavia, Weltevredan, Java.

17. *Personalia*—Prof. *August von Schmidt*, formerly head of the Meteorological Geophysical Section of the Württembergisches Statistisches Landesamt, Stuttgart, died on March 21, 1929, at the age of 90 years.

Colonel *E. Lester Jones*, Director of the U. S. Coast and Geodetic Survey, died at the age of 52 years on April 9, 1929, after fourteen years of service. His viewpoint towards those subjects that deal with the entire Earth was a broad one. He did everything in his power to encourage international cooperation. *Raymond S. Patton*, hydrographic and geodetic engineer, has been appointed director of the Survey to succeed Colonel Jones.

Dr. *Joseph S. Ames* has been elected president of the Johns Hopkins University at Baltimore, Maryland.

On October 1, 1928, Prof. *Adolf Schmidt* retired from the directorship of the Meteorlogisch-Magnetisches Observatorium bei Potsdam with which he had been connected since 1902. He retains the direction of the theoretical work of the Magnetic Observatory. On the same date, October 1, 1928, Dr. *R. Süring* was appointed Director and Professor of the whole Observatory and Dr. *A. Nippoldt* was made Chief of its Magnetic Division.

Prof. *G. Angenheister*, chief of division at the Geodätisches Institut in Potsdam, has been appointed Professor of Geophysics at the University of Göttingen.

Prof. *Adolf Schmidt* has been elected corresponding member of the Prussian Academy of Sciences.

Prof. *A. Wigand* left Stuttgart on April 1, to enter upon his new duties as Ordentlicher Professor of Meteorology and Director of the Meteorological Institute of the University of Hamburg as well as Chief of the Meteorological Experiment Station of the Deutsche Seewarte at Hamburg. His present address is Alsterkrugchaussee 124, Hamburg 20, Germany.

W. J. Rooney, Associate Physicist of the Department of Terrestrial Magnetism, is preparing to undertake an earth-resistivity survey at the site of the Department's magnetic observatory near Huancayo, Peru, and sailed from New York on May 9. This survey will yield data for the determination of the actual current-densities from the earth-current records being made at the Observatory. Mr. *Rooney* made a similar survey at the site of the Watheroo Magnetic Observatory and, with *O. H. Gish*, at the Ebro Observatory (see this JOURNAL, v. 32, pp. 49-63).

Prof. *S. A. Deel*, of Baker University, will spend the summer making magnetic observations for the U. S. Coast and Geodetic Survey in the Middle Western and Rocky Mountain states. Lieut. *J. A. McCormick*, of the Coast Survey staff, is now making observations in Texas, and will occupy additional magnetic stations during the summer in the Northwest and on the Pacific Coast.

Scott E. Forbush, of the staff of the Huancayo Magnetic Observatory, sailed from Peru on June 12, to join the ship *Carnegie* at San Francisco in July. His place at the Observatory will be taken by *Robert E. Gebhardt*, recently appointed assistant physicist in the Department of Terrestrial Magnetism, who will sail from New York on June 20.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Batavia. Observations made at the Royal Magnetical and Meteorological Obervatory at Batavia, v. 47, 1924. Published by order of the government of Netherlands East-India by Dr. J. Boerema. Batavia, 1928 (xix+110 with 3 plates of curves). 36 cm. [Contains magnetical observations made in 1924.]

Australasian Antarctic Expedition, 1911-14. Scientific reports. Series B. Vol. II. Terrestrial magnetism and related observations. Part II. Magnetic disturbance and its relations to aurora, by Charles Chree. Sydney, A. J. Kent, Govt. Printer, March, 1929 (193-331). 31 cm. Price, 15 shillings.

Chapman, S. On the theory of the solar diurnal variation of the Earth's magnetism. London, Proc. R. Soc., A, v. 122, 1929 (369-386).

Chapman, S., and J. M. Stagg. On the variability of the quiet-day diurnal magnetic variation at Eskdalemuir and Greenwich. London, Proc. R. Soc., A, v. 123, 1929 (27-53).

Chree, C. The regular diurnal variation of magnetic declination at Kew Observatory from selected years of many and few sunspots 1859-1894. London, Met. Office, Geophys. Mem., No. 43, 1928 (33). 31 cm.

Comité National Français de Géodésie et Géophysique. Compte rendu de l'Assemblée Générale du 2 juillet 1928, publié par le Secrétaire Général G. Perrier. Paris, Société Générale d'Imprimerie et d'Edition, (59). 24 cm. [Annexe 4, pp. 31-36, contains a general report on the activities of the French Section of Terrestrial Magnetism and Electricity.]

Eblé, L., et J. Itié. Valeurs des éléments magnétiques à la Station du Val-Joyeux (Seine-et-Oise) au ler janvier 1929. Paris, C.-R. Acad. sci., T. 188, No. 12, 1929 (875).

Gehlinsch, E. Ueber den Zusammenhang zwischen der Fleckentätigkeit auf der Sonne und den Störungen des erdmagnetischen Feldes. Riga, Mitt. Inst. Theoret. Astr. u. Analyt. Mechanik, Lettländ. Univ., Nr. 3, 1928 (77-185).

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Heiland, C. A., and W. H. Courtier. Magnetometric investigation of gold placer deposits near Golden, Colo. New York, N. Y., Amer. Inst. Min. Metall. Engin., 1928 (21). 23 cm.

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Mathias, E. Le magnétisme terrestre dans les possessions françaises du Pacifique. Proc. Third Pan-Pacific Sci. Cong., Tokyo, 1926, v. 2, 1928 (1348-1350). [With English abstract.]

La carte magnétique de l'Indo-Chine. Proc. Third Pan-Pacific Sci. Cong., Tokyo, 1926, v. 2, 1928 (1351-1354). [With English abstract.]

Maurain, Ch. Contribution à la connaissance du champ magnétique terrestre dans la région du Pacifique. Proc. Third Pan-Pacific Sci. Cong., Tokyo, 1926, v. 2, 1928 (1346-1348). [With English abstract.]

MURAMOTO, A. A magnetic survey of Japan for the epoch 1923.0, executed by the Hydrographic Department. Proc. Third Pan-Pacific Sci. Cong., Tokyo, 1926, v. 2, 1928 (1342-1345).
On the "Nippon Suirobu (Japanese Hydrographic Department) Magnetometer." Hydrogr. Bull., Tokyo, 8th year, No. 3, Mar. 1, 1929 (111-128 with 5 pls.).

N(EWTON), H. W. Magnetic storms and solar activity during 1928. Observatory, London, v. 52, Feb., 1929 (49-51).

NIPPOLDT, A. Der Erdmagnetismus. Müller-Pouillets Lehrbuch der Physik, 11. Aufl., 5. Bd., 1. Hälfte, Physik der Erde, Kap. 6 (398-484). Braunschweig, Fr. Vieweg u. Sohn, 1928. [Mainly a revision of the corresponding chapter (XV) of the 10th edition of the Lehrbuch which appeared in 1914. The plan of the preceding article has been followed very closely but much of the old matter has been rewritten and some new material introduced to take into account recent advances in the subject. Thus a description of Ad. Schmidt's field balance for horizontal intensity and sections on the distribution of terrestrial magnetism in Europe accompanied by three isomagnetic maps, epoch 1925.5, and on the magnetism of the Sun and Earth have been added. Also a new chapter on earth-currents has been included. The section on polar lights which appeared in the previous article has been omitted since this subject has been adequately treated by G. Angenheister in the following chapter of the Lehrbuch.]

OVCHINNIKOV, N. V. Bestimmung der magnetischen Deklination in Transbaikalien im Jahre 1926. Irkutsk. Verh. Mag. Met. Obs., No. 2-3, 1928 (174-177). [Text russisch mit deutschem Auszug.]

PUIG, I. El mapa magnético de España. Ibérica, Barcelona, Año 16, Núm. 770, 1929 (184-187). [Contains isomagnetic maps of Spain for declination, inclination, and horizontal intensity for the epoch 1924.0.]

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RÖSSIGER, M. Die Messung der Horizontal- und der Vertikalintensität des erdmagnetischen Feldes mit dem Magnetron. Zs. Instrumentenk., Berlin, Jahrg. 49, Heft 3, 1929 (105-113): Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 7/8, 1928 (371-372). [Es wird ein Apparat beschrieben, mit dem die Horizontal- und die Veritkalintensität des erdmagnetischen Feldes nach einer Nullmethode absolut gemessen werden kann, wobei ein Elektronenrohr (Magnetron) als Indikatorinstrument dient.]

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B—Terrestrial and Cosmical Electricity

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BERCE, R. Les hautes tensions électriques et l'énergie de l'éclair. Ciel et Terre, Bruxelles, 45e année, 1929 (24-29).

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CLAY, J. Penetrating radiation. II. Amsterdam, Proc. K. Akad. Wet., v. 31. No. 10, 1928 (1091-1097).

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FORTESCUE, C. L., A. L. ATHERTON, AND J. H. COX. Theoretical and field investigations of lightning. Abstract: New York, N. Y., J. Amer. Inst. Elec. Engin., v. 48, Apr., 1929 (277-280).

GRAY, L. H. The absorption of penetrating radiation. London, Proc. R. Soc., A, v. 122, 1929 (647-668). [On the hypothesis that penetrating radiation is a type of γ-radiation, its absorption is investigated from the theoretical standpoint. 1. An attempt is made to establish a quantitative correlation between the ionization produced in an electroscope by penetrating radiation and the scattering absorption coefficient of the radiation. 2. The relative magnitudes of the ionization produced by primary and scattered radiations at any point are computed by approximate methods. 3. On the basis of these results the relation between the apparent absorption coefficient of a homogeneous isotropic radiation and the true scattering coefficient of the primary radiation is discussed. 4. The adequacy of the Klein-Nishina formulæ to account for the observed absorption and scattering of γ-rays is briefly discussed.]

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Terrestrial Magnetism and Atmospheric Electricity

VOLUME 34 SEPTEMBER, 1929 No. 3

ATMOSPHERIC-ELECTRIC RESEARCHES MADE IN 1928 DURING THE NOBILE ARCTIC EXPEDITION IN COLLABORATION WITH PROFESSOR A. PONTREMOLI (MILAN) AND PROFESSOR F. MALMGREN (UPSALA)

BY FRANCIS BĚHOUNEK

INTRODUCTION

The researches into atmospheric electricity made during the Arctic Expedition of General Nobile comprised partly the measurements made in the airship *Italia* (Fig. 1) during the flights (see Figs. 2 and 3) Milan to Stolp (Pomerania), Stolp to Vadsö to Kings Bay (Spitsbergen), Kings Bay to Franz-Josef Land to North Land (or Lenin Land) to Novaya Zemlya to Kings Bay, and Kings Bay to Greenland to North Pole to Charles XII Island (north of Spitsbergen), and partly the measurements made in Kings Bay on board the S. S. *Città di Milano*. The measurements included intensity of the penetrating radiation of the atmosphere, electric conductivity, ionic content, potential gradient, and radioactivity of the air. This paper deals merely with the measurements made during the flights of the *Italia* and their interpretation.

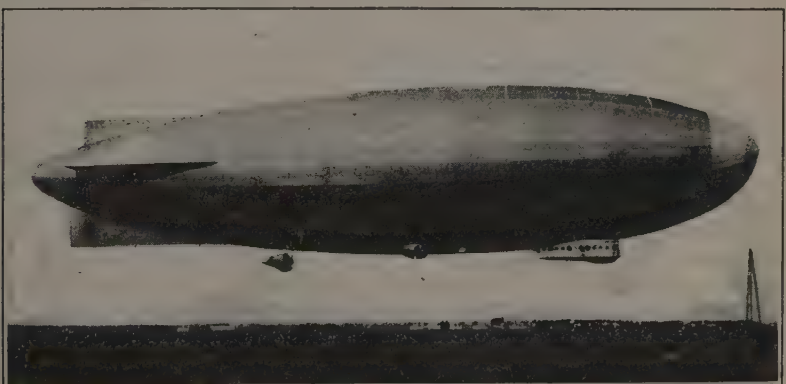


FIG. 1—Airship *Italia* (capacity, 18,500 cubic meters; length, 106 meters; maximum width, 19.5 meters; maximum height, 26 meters; three 250-horse-power Maybach motors)

Apparatus and Methods Used

§1. *Penetrating radiation of the atmosphere*—The method of observation was the measurement of residual ionisation in a closed vessel. A Wulf-Kolhörster type[1] electrometer of 4000-cc content and 0.95-cm electric capacity was used. Quartz was used for insulation, the electrometer fibers being also made of this material. The distance between the fibers is dependent only on the electric charge given to them by means of a small magnetic device, being independent of temperature and varying only very slightly even if the apparatus is strongly inclined. The average sensitiveness of the electrometer, in case of microscopic reading, amounts to about 1.3 volts for one small scale-division. The 3-mm zinc walls reduce to a negligible value the influence of the β-rays of the radioactive substances contained in the air. The apparatus, constructed in 1922 by Günther and Tegetmeyer (Brunswick), before being used on this Expedition was cleaned, was re-galvanised inside, and was provided with a new fiber-system. The spontaneous activity or wall-radiation was thus considerably reduced and, as is evident from the following, amounted to about $2.5J$, that is 2.5 pairs of ions produced every second in one cc of air. It was possible to close all the projecting parts of the electrometer air-tight and to submerge the apparatus in water. The electrometer itself was made air-tight and filled with dry air at atmospheric pressure.

The precision of the measurements made by this apparatus depends on (*a*) oscillations of the activity of the apparatus itself and (*b*) precision of reading of the situation of the fibers.

(*a*)—By spontaneous activity of the apparatus itself is meant the ionisation-current remaining after all outer penetrating radiation of the atmosphere is removed. Büttner[2] has proved that the greater part of this ionisation-current is caused by α-particles which are emitted by the radioactive impurities contained in the walls of the ionisation-vessel.

The oscillations of this ionisation-current are caused in two ways, namely, partly by the static character of the emission of α-particles causing an absolute average error of the observed ionisation-effect, and partly by the lack of saturation-current varying according to the change of the electric tension of the fibers.

If we assume that all ionisation-current given by the spontaneous activity of the apparatus used and equalling $i_0 = 2.5J$ is caused only by the α-particles, and on the assumption that one α-particle produces on its whole course about 1.5×10^5 pairs of ions (it being assumed that the ionisation-power of each α-particle is fully utilised), then an ionisation-current of 2.5×4000 pairs of ions per second or 1×10^4 pairs of ions per second would correspond to an emission of about 238 α-particles per hour. Thus for one-hour reading of the apparatus the average absolute error[3] would amount to

[1] W. Kolhörster, *Zs. Physik*, v. 5, 1921 (107).
[2] *Zs. Geophysik*, v. 2, 1926 (187).
[3] Meyer und Schweidler, Radioaktivität, 2. Aufl., p. 44.

$\sqrt{238}$ of α-particles, that is about 15.4 α-particles, which corresponds with an ionisation-effect $i_1 = (15.4/238)\ 2.5J = 0.16J$. For a reading every two hours this effect decreases, and thus also the corresponding error, to $i_1 = 0.11J$.

As regards the saturated current the distance of electrodes amounted to 10 cm and the range of the tension used was 200 to 100 volts. According to Moulin[4], for an electric field of 10 volts per cm, the measured value of ionisation is 0.73 of the value of the saturated current when the direction of travel of the α-particle is parallel to the direction of the field and 0.83 of this value, when the two directions are perpendicular to each other.

For intensity of electric field 20 volts per cm the corresponding figures are 0.78 and 0.91. From these data the average error (i_2) when the tension of the electrometer-fibers varies from 200 up to 100 volts is determined as about 6 per cent of the value measured; therefore for the given case i_2 becomes $0.06\, i_0 = 0.15J$.

(*b*)—The precision of reading the situation of the fibers was—in

FIG. 2—Chart showing route of *Italia* from Milan to Kings Bay (original reduced one-half)

[4]MEYER UND SCHWEIDLER, *ibid*, p. 281.

view of the slight vibrations of the electrometer caused by the rotation of the propeller—about ± 0.2 scale-division for each fiber and therefore the maximum error (when read twice) was $\pm 4.0 \times 0.2 = \pm 0.8$ scale-division, which corresponds to a maximum average error $i_3 = 0.48J$.

For readings every two hours, the interval chosen to decrease the total percentage of error, the maximum possible error amounted to $i = i_1 + i_2 + i_3 = 0.74J$. As the total measured ionisation-effect (spontaneous ionisation plus ionisation caused by the penetrating radiation of the atmosphere) amounted to an average of $9J$ in two hours, the maximum percentage of possible error amounts to $+8.2$ per cent.[5]

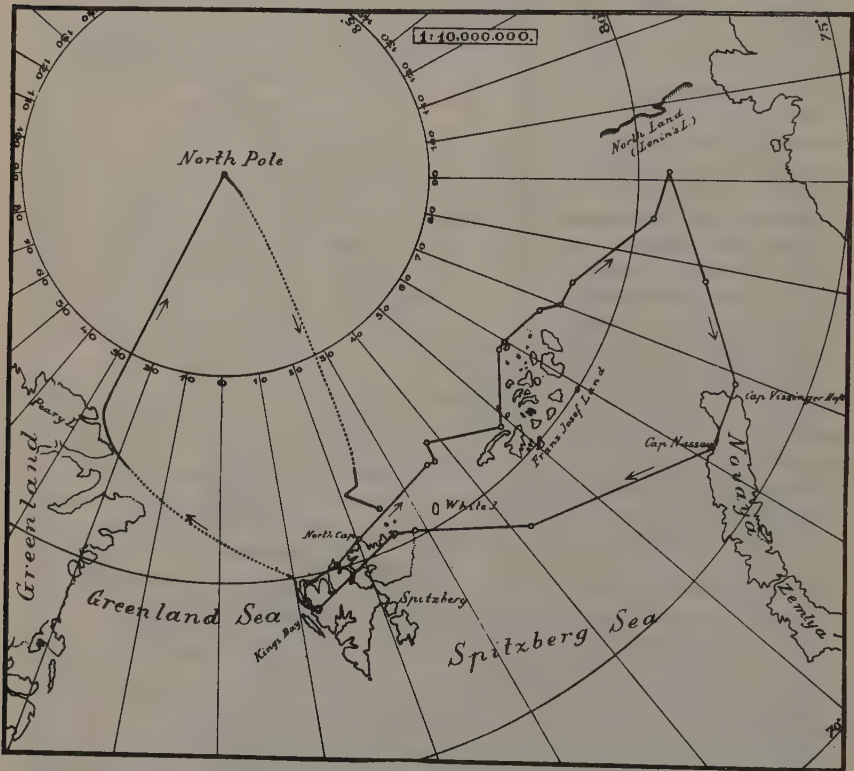


FIG. 3—Chart showing Arctic flights of the *Italia* (original reduced one-half)

§2. *Ionic content and electric conductivity of the atmosphere*—As it was necessary to reduce weight of equipment to a minimum both these quantities were measured by the Gerdien apparatus

[5]In existing literature on penetrating radiation, dealing frequently with observations of the oscillation of this radiation, discussion of errors of observation similar to that of this paper has been made only in rare cases.

which was somewhat modified to this end (see Figs. 4 and 5). The vertical tube t_1 containing the electrode terminated at one end in the tube t_2 while at the other end the anemometer A was mounted in the vertical tube t_3 connected with the tube t_4. The tubes t_1 and t_4 projected through the linen walls, so that the air passing through the tubes was led out again without troubling the crew.

The tube t_2 was free to revolve round the horizontal axle and its angle with the longitudinal axis of the airship could be read on the graduated ring c. It could be clamped in any desired position by means of the screw s. As the flow of air in the tubes was caused by the motion of the airship itself, without using the fan, it was

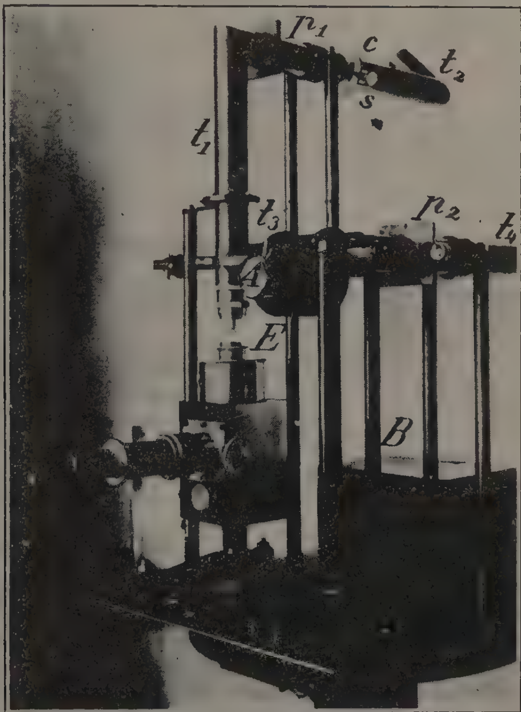


FIG. 4—Detail view of aspirator for ionic content and conductivity of the atmosphere

possible, by the inclination of t_2 (through which the air entered), to regulate its rate from zero (practically) to a definite maximum value based on the speed of the airship. As known the following condition is valid for the Gerdien aspirator

$$G \gtreqless 2klV/[(r^2_1 - r^2_2) \log_e (r_1/r_2)]$$

where G = speed of air stream; k = ionic mobility; l = length of the electrode, r_2 its raditus, V its potential; and r_1 = inside radius of the tube t_1 containing the electrode.

If G is greater than the right-hand side of the equation, the aspirator fulfills the condition of recording ions; if G is smaller the apparatus fulfills the condition for measuring the electric conductivity of air.[6] By means of the anemometer A the amount of

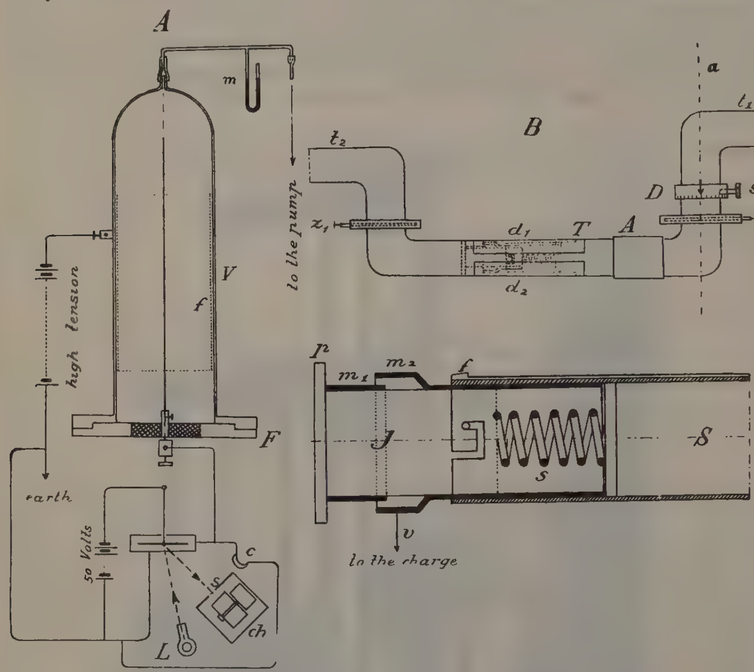


FIG. 5—Schematic diagrams, radioactive-content apparatus

air was controlled so as to give the exact fulfillment of the above condition. The aspiration part was completely separated from the electrometer E and connected to it by a wire only (electrostatically protected by a short connecting pipe which is not shown in the drawing), so that it was possible to use any desired electrometer. The electrode together with its amber insulation could be easily unscrewed and removed from below so that it was possible to clean the insulation easily. This proved very advantageous especially during the flights in fog when moisture settled down on the insulation, in spite of the fact that the electrode had a special circular protecting plate covering the amber.[7] The tubes

[6] As a matter of fact it is also possible to affect these conditions by changing the electrode-potential V, but the sensitiveness of the electrometer used did not permit varying V in large limits and the variation of speed of the air-stream was much more convenient.

[7] That this plate may offer good protection against moisture it is necessary to reduce the distance between same and the exposed amber surface to a minimum.

t_1 and t_3 could be closed inside the cabin by the plugs p_1 and p_2, and in addition to this the tubes t_2 and t_4 could also be closed from outside by lids on the outer wall of the cabin. The tube t_4 through which the air passed out was parallel to the beam of the airship and thus at an angle of 180° to the direction of flight. The electrometer with the electrode was charged by a special probe (not shown in the illustration) connected to a battery of small Weston elements of 200 volts arranged in 10-volt steps. A bifilar Wulf electrometer having a sensitivity of 0.5 volt per scale-division was connected to the aspirator. Unfortunately, this electrometer was too sensitive to vibrations caused by the rotation of the motors and in spite of all efforts and an elastic suspension we could not succeed in obtaining satisfactory readings with it. This fact prevented measuring the ionic content and the conductivity of air during any of the flights except the last one, namely the flight from Greenland to the North Pole. Another Wulf electrometer was then used with a sensitivity of 1.8 volts per scale-division; it could be read with a precision of at least ± 0.2 scale-division. Thus the maximum reading error (in the case of two readings and two fibers) was ± 0.8 scale-division and as the minimum value read during one observation was 8 divisions, the maximum possible error was ± 10 per cent. The dimensions of the apparatus were: r_1, 1.5 cm; r_2, 0.2 cm; l, 10 cm; total electric capacity, 13.3 cm.

To make a complete measurement for electric conductivity of air two minutes were quite sufficient, and for ionic content of one sign, four minutes were needed. Thus one series of measurements, that is positive and negative conductivity (or positive and negative ionic-content) with the necessary manipulations, took 14 minutes. From this it is evident that the values obtained are means for an average flight-distance of 16 km at the average speed of the airship relative to air of 70 km per hour, and of 23 km at the maximum speed of the airship of 100 km per hour.

§3. *Potential gradient*—The potential gradient was measured as suggested by Professor A. Pontremoli by apparatuses specially provided by him of the Wigand type[8]. The collector was of the vane type suggested by Wigand (see Fig. 6*B*), provided with a spherical plate *d* and vanes *h*, so as to create an air-whirl around the active surface *l*. Thus the speed at which the collector takes up the potential of the surrounding atmosphere is practically independent of the speed of the air-stream. The collector was made of aluminium, the diameter of the plate *d* and the span of the vanes amounted to 15 cm; the diameter of the axle supporting the active surface was 3 cm and the length of the surface was 10 cm. Polonium on a silver plate was used for the active substance; it was placed electro-mechanically by the J. Curie[9] method. The polonium-layer was made in the Czechoslovak Radiological Institute where

[8] A. WIGAND, *Fortschritte der Chemie, Physik u. Physik. Chemie, B*, v. 18, 1925 (10), and *Ann. Physik*, v. 85, 1928 (333).

[9] *Chimie Physique*, v. 22, 1925 (471).

an investigation was made of the varnish coating to protect the polonium-layer against the influences of weather. Of the eight various varnish paints used "Zapon" varnish[10] proved best; when diluted in amylacetate and applied in a thin layer on the polonium it decreased the intensity of its α-rays by 27 per cent only. In addition to this it completely resisted the influence of moisture and its effectiveness did not change even when immersed in water 24 hours.

The collector was fastened by amber insulation to a movable wooden arm *a* revolving in the bearing *r*. When lowered by means of the cord *s* (Fig. 6*A*), operated from the cabin, this arm maintained an unchanged direction forming an angle of 45° with the longi-

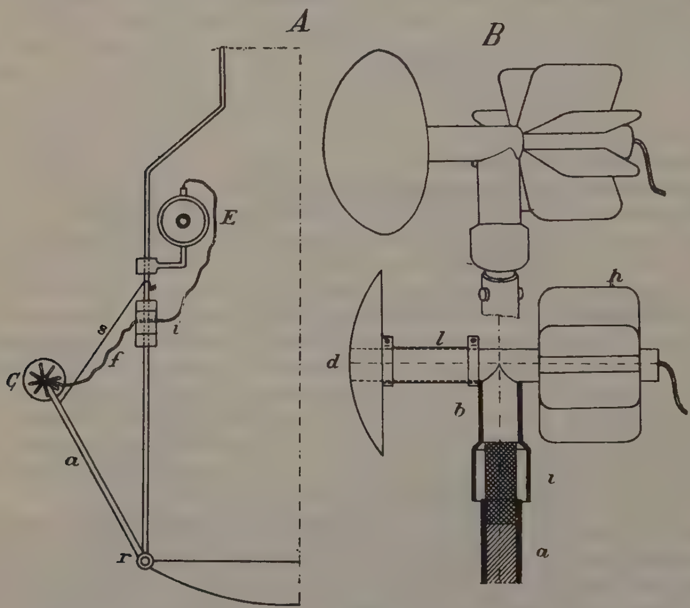


FIG. 6—Schematic diagrams, potential-gradient apparatus and Wigand vane-collector

tudinal center line of the cabin. At the same time the collector was at a distance of one meter from the cabin-wall and therefore the potential difference between this point and the airship body was measured. By means of the electrically conducting cord *f* through the amber insulation inserted in the cabin-wall the collector was connected to the probe, which was either earthed (that is connected to the metallic structure of the airship), or connected to the electrometer *E*. When not in use, the movable arm was held to the cabin-wall by the cord *s*. The electrometer *E* was also

[10]Celluloid dissolved in amylacetate.

provided with a movable arm and it was possible to move it close to the inside wall of the airship.[11]

The Wiechert-type electrometer, with quartz filaments and a measuring range of 0 to 300 volts, was used for observation. The electrometer was very insensitive to mechanical vibrations and shocks; it did not record however the sign of electric tension and this had to be controlled by the inductive effects of an amber rod. The collector-action was very quick and the period in which the charge of the whole system was reduced to one per cent of the initial value was less than one second[12] at an average speed of the airship of 70 km per hour. If the airship has no electric charge of its own it is possible, from measurements on a model of the airship placed in an artificial electric field, to ascertain empirically the reduction-factor and by multiplying the values measured in the airship by this factor, to obtain the actual values for the electric field of the atmosphere as it would be when not disturbed by the presence of the airship. Unfortunately the 250-horse-power Maybach motors of the *Italia* had electrically charged exhaust gas and hence during the use of the motors, the airship also took on a certain charge dependent on their speed of rotation.

Before leaving Milan this fact was experimentally ascertained as follows: A thick net was held by an ebonite handle against the exhaust pipe of one of the motors and the net was connected to the filaments of the Wulf electrometer. The gas coming out of the pipe was compelled to pass through this net. This test showed that the electrometer gained a charge which increased with the number of revolutions of the motor.

At full speed of a single motor (more than 1350 r. p. m.), this charge was higher than the range of the electrometer, which amounted to 120 volts. The sign of the charge of electrometer was negative, so that the airship was charged positively. The magnitude of the charge could not be ascertained experimentally and consequently these measurements are of importance only in so far as they make it possible to compare, in main features, the values obtained above Central Europe with the values measured above the Arctic Ocean. On account of the motor-rotations the airship will take on a constantly increasing charge until the decrease of charge given by its leakage from the airship-surface to the surrounding atmosphere is equal to the increase of charge caused by the motor-rotation and the outgoing exhaust-gas. It is evident, therefore, that the balance, and thus also the absolute value of the airship-charge, will depend on the air-speed and on the ventilation of the ship's surface. The resulting states for various air-speeds and for various atmospheric changes (density of the electric charge of the atmosphere, air-moisture, and the like) cannot be found theoretically, nor can they be ascertained experimentally. The

[11]This arrangement was necessary for economy of space in the commander's cabin the dimensions of which were very small.

[12]The intensity of the α-ray corresponded to about 11,000 ESU.

only means would have been to provide powerful collectors which would have caused a rapid leakage of the airship-charge into the surrounding atmosphere, but there was not time for this as it would have been necessary also to measure their efficiency.

§4. *Radioactivity of atmosphere*—The researches into the radioactivity of atmosphere met with great difficulties, partly because of the difficulty in measuring the very small electric currents which are involved and partly because of the complicated methods in use up to the present. For technical reasons, it was also impossible in the case of long flights to follow the Wigand method,[13] using liquid oxygen for condensation of radium-emanation.

A quite different method was used therefore; it is based also on the capture of atoms of the active deposit but the measurement for the last product of the radioactive transformation, i. e. polonium, was made in the laboratory. Thus the observations in the airship were considerably simplified and were limited to the capture of radioactive atoms. Their number was then measured in the laboratory by counting the α-particles emitted by the last transformation product, i. e. polonium. The Rutherford-Geiger[14] method was used, the only changes being that the diameter of the counting vessel V was increased to 4 cm and that its closing lid was made detachable. The increased diameter was to insure the α-particles flying in the shortest direction, i. e. vertically to center line of the vessel, to produce an effect noticeable by the ionisation by collision. The calibration, made by means of polonium, showed this really was the case.[15] By using this method it was also possible to follow the decrease of the active deposit of radium of short life and the gradual formation of polonium from this, thus showing it possible to use this method for quantitative measurements. The measuring apparatus is clearly shown in Fig. 5. The outside tube of the counting vessel which is of brass and about 30 cm long is connected to the negative high-tension pole; the central wire is of steel and has a diameter of 0.1 cm and, passing through the insulating amber-plug, it is connected to one pair of quadrants of the Compton electrometer of which the second pair of quadrants is earthed and the needle is charged to -50 volts. The first pair of quadrants is also earthed but through a Campbell liquid resistance C (one part of alcohol and ten parts of xylol). The mirror of the needle reflects, through the narrow slit s of the photographic camera ch the image of the straight fiber of the lamp L onto the sensitive silver-bromide paper in one layer around a 12-cm diameter

[13]A. Wigand, *loc. cit.*, and *Ann. Physik*, v. 86, 1928 (657).

[14]*Proc. R. Soc.*, A, v. 81, 1908 (141). Already in this first work the authors claim the following: "There is no doubt that the principle of automatic increase of the ionisation by collision can be used to extend considerably the range of measurement of minute quantities of radioactive matter." Up to the present however this sensitive method has not been used as indicated.

[15]A correction-term must be applied for the α-particles which have a very short range before reaching the walls of the detecting vessel. It was determined experimentally and its value is 1.06. The registered number of α-particles must be multiplied by this term to obtain the true value.

clock-drum revolving once per 24 hours.[16] The counting vessel is connected, over the shortened pressure gauge m, to the Cenco-Hyvac air-pump. The activated foil f, the activity of which is to be measured, is inserted in V. Sheets of tin foil some hundreths of a millimeter thick were used; these are very flexible and adhere perfectly to the walls without the necessity of any fixing device. During observations an air-pressure of about 4.5 cm of mercury was used inside the chamber and a tension of 1400 volts on its shell. In view of the small capacity of the whole system (about 24 cm) a sensitiveness of the electrometer of 2000 mm per volt (the distance between paper and needle being one meter) was sufficient for attaining a large throw of the electrometer-needle. The apparatus used in the airship is very simple. In the brass tube T (Fig. 5B) a brass coaxial cylinder is fixed to the amber insulation J and protected, as far as possible, by the shells m_1 and m_2 against the influence of air. The cylinder is fixed in the tube T by the cross piece p and is connected by the wire v to an insulated terminal outside connected to the tube T. A bayonet-shaped closing-device permits mounting on this cylinder the hollow cylinder S on the outside of which a sheet of tin foil is fixed by the spring f in the same way as the record-sheet of a barograph is fastened. Loosening of the cylinder S because of vibrations during the flight is prevented by the spiral spring s. The diameter of the cylinder S is 3 cm so that the distance of the exposed tin foil from the walls of the tube T is one cm. Under these circumstances a tension of 100 volts supplied by the dry battery to the cylinder S is sufficient to arrest on the tin foil all radioactive atoms of the normal mobility, approximately 1 cm/sec per volt/cm. In order that it may be possible to change the speed of air the arm t_1 is arranged in such a way that it can revolve round the axis a and its angle to the ship's fore-and-aft can be read on the graduated ring D. The screw s is used for clamping the arm. The speed of the air drawn in, on which the fulfillment of the condition for arresting of all electrically charged radioactive atoms of normal mobility depends, is controlled by the anemometer A. The air passes out again through the tube t_2 and the tube T can be closed by the shutters z_1 and z_2. It has been ascertained experimentally that at an aspiration-speed not exceeding two liters per second all the atoms will settle down in the first half of the cylinder S so that the metallic shell m_2, although it is also charged electrically, remains nonactive. By using this apparatus the operations during flight consist only in replacements of tin foil (as in the case of a barograph) and in recording of time and amount of air drawn in. All measurements are then made at any later time in the laboratory.

This precision and sensitiveness of the method is limited partly by the imperfect knowledge of the period of radium D, partly by

[16]The use of clock-drums with a single layer of photographic paper as for the barograph, is more precise and simple than the method of unwinding the photographic paper by means of two rollers. For intensive sources of polonium a clock-drum was used whose speed of rotation could be varied from 4 minutes to 3 hours.

the self activity of the tin foils, and partly by the error possible in counting the α-particles in view of the statical character of the transformation law. Finally the activity measured in this way indicates only the activity given by the radioactive atoms electrically charged whereas the atoms not charged are not arrested. The conclusions concerning the total radioactivity of the atmosphere, therefore, can only be made on certain assumptions.[17]

All short-life atoms arrested on the tin electrode are completely transformed in several hours to radium D. Designating this period as t_0, the amount of radium D as D_0, and the amount of polonium measured after a certain period t as RaF, then RaF is derived by a known equation resulting from the exponential character of the transformation law

$$RaF = D_0\ (k_1e^{-\lambda_D t} + k_2e^{-\lambda_E t} + k_3e^{-\lambda_F t})$$

where

$$k_1 = \lambda_D\lambda_E/(\lambda_E - \lambda_D)\ (\lambda_F - \lambda_D);\ k_2 = \lambda_D\lambda_E/(\lambda_F - \lambda_E)\ (\lambda_D - \lambda_E);$$
$$k_3 = \lambda_D\lambda_E/(\lambda_D - \lambda_F)\ (\lambda_E - \lambda_F)$$

It is therefore evident that in ascertaining D_0 on the basis of the measured values RaF the result depends on t and on λ_D, λ_E, λ_F, that is on the transformation constants of RaD, RaE, RaF.

Now λ_E and λ_F are known with sufficient precision but not λ_D. The old value[18] for λ_D is 1.187×10^{-4} day^{-1}. Recently E. A. W. Schmidt[19] has fixed the half-value period of RaD as 25 years, from which it follows $\lambda_D = 0.760 \times 10^{-4}$ day^{-1}. If we assume $\lambda_E = 0.1429$ day^{-1}, $\lambda_F = 5.078 \times 10^{-3}$ day^{-1}, and $t = 300$ days, which corresponds on the average to the time elapsed between the activation of the tin foils and measurement of the produced polonium, we get $\lambda_D = 1.187 \times 10^{-4}$ day^{-1} $RaF = 0.0177$ for $D_0 = 1$; for $\lambda_D = 0.760 \times 10^{-4}$ day^{-1} we get $RaF = 0.01141$. The latter result is smaller by 0.00630 or by 35.6 per cent, which is the amount of error resulting from the uncertainty as far as the exact value λ_D is concerned.

Another error is caused by the natural activity of the tin foil. About 50 foils were measured before use and of these 20 also after an interval of 12 months, during which time they were stored in a non-active place. These 50 measured foils showed activities, which varied considerably, ranging between 15 and 80, that is in counting the α-particles amounting to 15 to 80 α-particles per 24 hours. The corresponding average absolute errors, the square roots of 15 and 80, therefore are 3.87 and 8.94; the average percentage error is $1/Vz$, namely 25.8 and 11.2 per cent.

The sensitiveness of the method is thus limited. If the result

[17] F. Běhounek, *J. Physique*, v. 8, 1927 (161).

[18] Meyer und Schweidler, *loc. cit.*, p. 457.

[19] *Mitt. Inst. Radiumforschung*, Wien, Nr. 227, 1928.

is to be guaranteed as to quantity, the measured activity must give the number of α-particles at least ten times larger than the maximum spontaneous activity, therefore 800 per 24 hours. As an equal number of α-particles escapes measurement (α-particles are emitted into the walls of the counting vessel) we have a total emission of 1600 α-particles per 24 hours which corresponds to 5×10^{-13} gram of radium, computed on the basis of the Lawson-Hess number,[20] namely 3.72×10^{10} α-particles per gram of radium per second.

As the average amount of air drawn in for each foil amounted to 10 m^3, it is evident from this result that (except for the influence of λ_D) a radioactive emanation-content of the order of 5×10^{-20} Curie per cm^3 may be determined with a precision of some few per cent.

Installation of the Apparatus in the Airship

All the apparatus was placed in the commander's cabin. The Wulf-Kolhörster electrometer and apparatus for measuring the ionic content and the conductivity of air as well as all batteries were mounted on the cabin-railing (Fig. 7). The Wiechert electrometer and the apparatus for the capture of radioactive atoms were mounted at the top of the cabin-wall. All installations of the apparatus were made under the supervision of General Nobile. All equipment was protected against the shocks of the airship and the vibrations caused by the working motors, by means of steel spirals and rubber washers. As is evident from Fig. 1 the distance from the commander's cabin to the central motors was considerable (about 20 meters) so that the vibrations caused by the motors were much reduced at the instruments. By placing the apparatus in the commander's cabin, therefore, in the front part of the airship, a proper purity of the air drawn in was assured as the exhaust gases escape towards the rear. Also the polonium-collector was placed in such a way that the ions produced by it could not be transmitted into the air drawn in by the apparatus.

The greatest difficulties when measuring in the arctic zone were caused by the moisture of the air and by the low temperature. The Zamboni pile of a tension of about 300 volts used for charging the Wulf-Kolhörster electrometer lost its tension when the air reached a temperature of less than $-15°$C and humidity ranging between 70 and 100 per cent; it was only after the pile was heated for a longer period by placing it in the pocket of an inside suit that its tension partly regenerated. The moisture settled down on the insulator of the apparatus for measuring the ionic content. The insulator had to be dried all the time and the controlling measurements of the spontaneous discharge of the apparatus had to be made before and after each series of measurements.

[20] Hess-Lawson, *Wiener Berichte* (II*a*), v. 127, 1918, (405, 462, 536, 599).

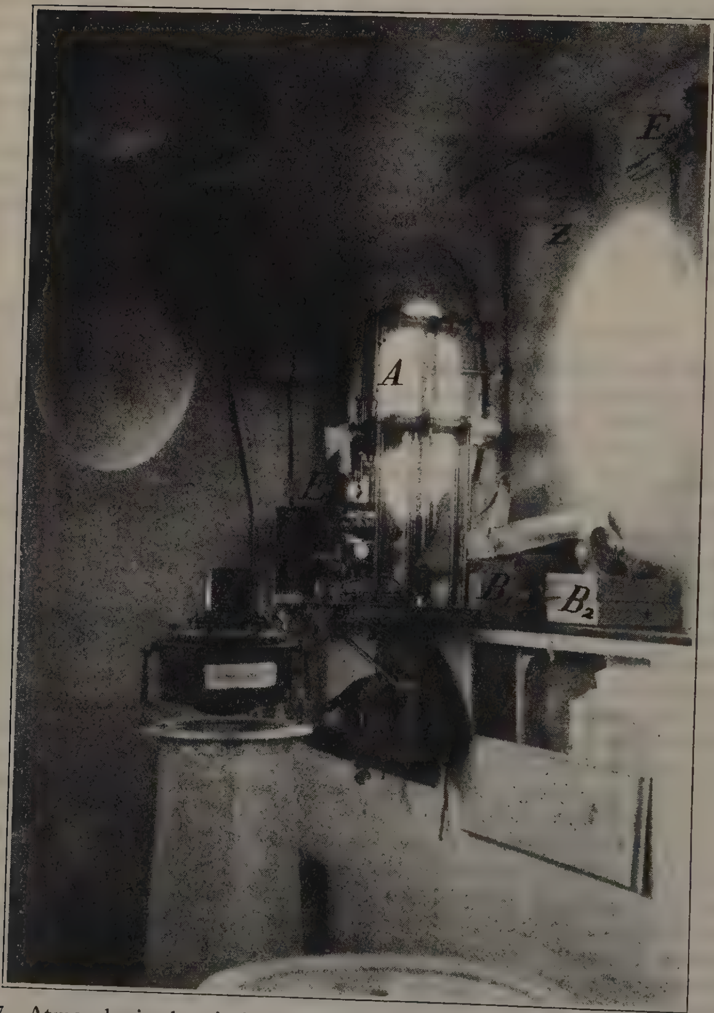


FIG. 7—Atmospheric-electric installation in commander's cabin, Airship *Italia* (E_1, Wulf-Kolhörster penetrating-radiation electrometer; A, aspirator for measuring ionic content and conductivity of the atmosphere; E_2, Weichert electrometer for potential gradient; Z, Zamboni pile; B_1, B_2, dry batteries)

Discussion of the Results

§1. *Penetrating radiation of atmosphere*—The most exact observations were those of the ionisation in a closed vessel. The measurements were made during all flights and after the airship was wrecked[21] and also on the pack-ice.[22] The results of the measurements are shown in the Tables 1 to 5 and in Figures 8 to 11 where

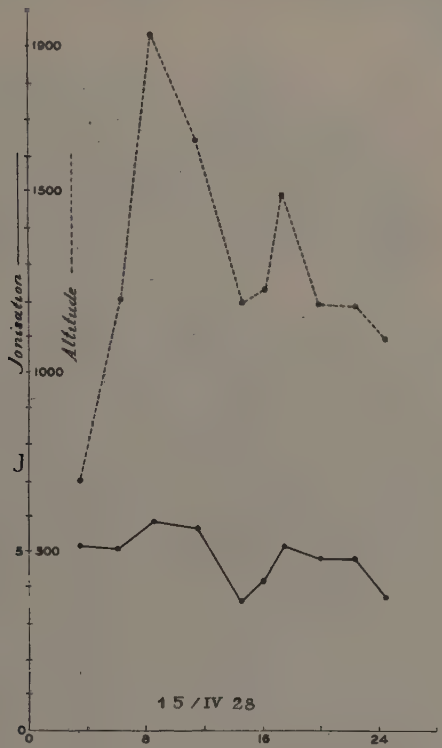


Fig. 8—Graphs of results, April 15 to 16, 1928

the ionisation-values obtained in units J (J = one pair of ions per cc per second) are shown as ordinates and the time as abscissas. The broken lines indicate the average heights above sea-level of the airship figured by a graphical method from the barometric registrations.[23]

Before interpreting the results I should like to give the mean values for J obtained from measurements made at six land stations

[21] The airship was wrecked on May 25 at 10^h30^m G. M. T. (latitude, 81° 14′ north; longitude 25° 25′ east).

[22] As the high-tension batteries were destroyed when the airship collapsed the electrometer was charged statically by means of an amber cigarette-holder.

[23] The height-curve for Fig. 11 is an exception as it was necessary to use the individual records due to the fact that the barogram was destroyed when the airship was wrecked.

(the number of observations is indicated by the number in parentheses following the value; the number preceding the value is the height of the station above sea-level):

(1) Milan (Baggio), elevation	122 m	7.3	(18)
(2) Stolp (Seddin)	60 m	6.9	(26)
(3) Vadsö	30 m	5.4	(12)
(4) Kings Bay (Spitsbergen)	12 m	4.0	(18)
(5) Pack-ice	0	2.9	(21)
(6) Pack-ice	−15 m	2.5	(4)

The last value (6) was obtained by lowering the apparatus into the Polar Sea to ascertain its self-activity; the number of observations was limited as the ice was constantly moving. The apparatus was submerged during two hours only for each observation because of the risk of crushing and loss of the apparatus, due to the movement of the ice-packs, involved in any longer submersion. The precision of the value obtained (2.5 J) is theoretically within ±10 per cent and actually the four values obtained fell within this range.

The gradually decreasing ionisation-values for Milan, Stolp, Vadsö, and Kings Bay are also dependent on the Earth-radiation. Milan as a continental town has the highest value. The proximity of the sea decreases this value considerably in the case of all other places as naturally might be expected in view of the lack of radioactive substances in sea-water. During the measurements at Kings Bay the Earth-radiation was absorbed by a thick layer of snow. From the initial values of the ionisation-curves of Figures 8 and 9 it is evident that the ionisation-values at heights between 250 and 1000 meters did not differ greatly from one another and that no increase of penetrating radiation with increasing height can be noticed in this range (for measurements above the Continent)—as was also found by Hess.[24] From Figure 8 it is evident that where the airship had a height of 1000 meters above sea-level the ionisation-curve and the height-curve are parallel, although the absolute values obtained for approximately equal heights do not coincide with each other (for example, Nos. 5 and 8 of Table 1). The explanation for these two phenomena, namely, the approximate constancy of ionisation between 250 and 1000 meters and the noncoincidence of values obtained at corresponding heights above sea-level, where the influence of Earth-radiation should be zero, may be looked for in the following two conditions: (a) The Earth-radiation may reach up to a much higher height than 300 meters, as has been assumed up to the present,[25] and (b) the changes in concentration of the radioactive products in the air may have a greater influence than is generally attributed to them.[26] Certainly,

[24] *Mitt. Inst. Radiumforschung*, Wien, Nos. 9, 1911 and 30, 1912.

[25] K. Büttner, *Zs. Geophysik*, v. 3, 1926 (151).

[26] The influence of radiation of the radioactive substances contained in the atmosphere upon the ionisation in a closed vessel is generally estimated at only 0.1 to 0.3 J (see *e. g.* Angenheister, *Geophysik*, 1928, p. 493).

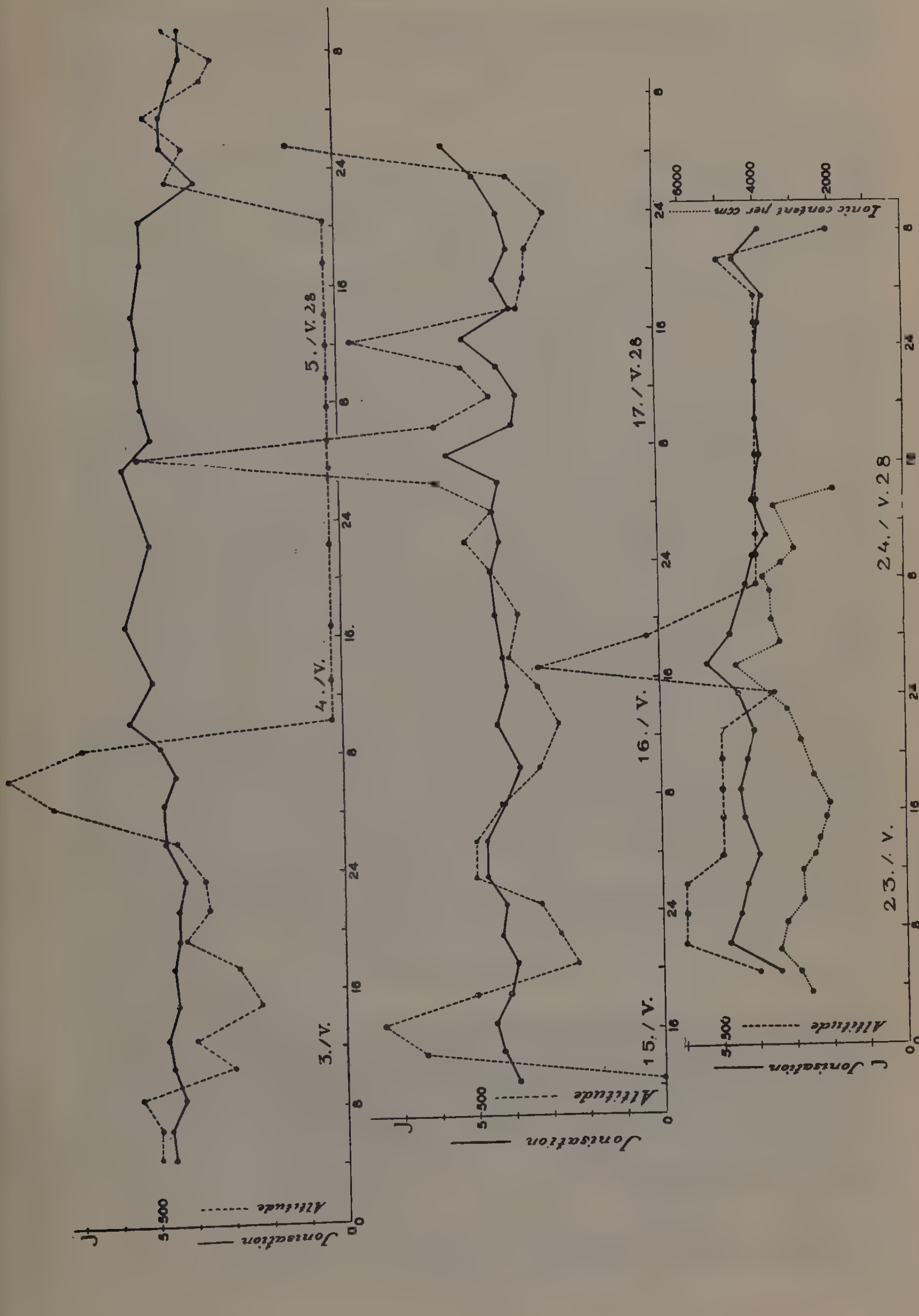


FIG. 9, 10, AND 11—Graphs of results, May 3 to 6, 1928; May 15 to 18, 1928; and May 23 to 25, 1928

as is evident from Table 1, the specific radioactivity of the atmosphere for station 8 was higher than that for station 5.

For the Earth-radiation, the value of the absorption-coefficient for air generally accepted is $\mu/\rho = 0.036\ cm^2g^{-1}$, where ρ = specific density of air. In the case of this radiation the ionisation-values at heights above 300 meters are practically negligible. The value however found by Hoffmann[27] for one hard component of γ-rays of radium C, that is, $\mu/\rho = 0.016$ for lead indicates a radiation the penetration of which in the atmosphere would be about three times greater than that of the foregoing one and it therefore could easily reach up to a height of 1000 meters.

The ionisation-curve of Figure 9 consists of three parts. The first one, obtained between Stolp and Vadsö, ranges slightly in the neighborhood of the average value 4.5 J for heights between 225 and 900 meters. The second one for values measured in Vadsö, when the airship was anchored to the mast, ranges in the neighborhood of the average value of 5.4 J, and finally the third one measured above Spitsbergen Sea, shows an average value of 4J for heights between 300 and 500 meters. This third part agrees approximately with the values obtained in corresponding heights above the Polar Sea. The lower values of the third part compared with the first may be explained by the lack of Earth-radiation above the sea. The radioactive substances contained in the sea being in a concentration more than 1000 times lower than that in the Earth's crust cannot contribute here to the ionisation of atmosphere and furthermore the influence of radioactive substances contained in the air must be very small.

The only substance the radiation of which could become important is the potassium contained in the sea-water. Recently Kolhörster[28] has ascertained that this element emits a strongly penetrating radiation of a coefficient of $\mu/\rho = 0.024\ cm^2\ g^{-1}$. It is possible theoretically to ascertain approximately the influence of radiation of potassium contained in the sea-water. For the radiation of the plane-parallel layer indefinitely thick containing radioactive element in a quanity of ρ per cc and absorbing its radiation in a way defined by the coefficient μ, an equation of the form

$$J = a\rho/4\mu$$

is valid for the radiation-intensity[29] if a is the so-called specific radiation, that is, the radiation emitted by one gram of element. For the potassium contained in sea-water we have[30] $\rho = 3.7 \times 10^{-4}g\ cm^{-3}$, and $\mu = 0.024\ cm^{-1}$. The specific radiation can be defined proportionally to the specific radiation of radium if we adopt for the

[27] *Physik. Zs.*, v. 26, 1925 (669).

[28] *Naturw*, v. 16, 1928 (28).

[29] Meyer und Schweidler, *loc. cit.*, p. 86.

[30] Doelter, Handbuch der Mineralchemie, v. 4, p. 1252.

half value period of potassium the Lawson value,[31] $T_k = 15 \times 10^{-11}$ years, and multiply by the ratio of atomic weights, because a conversion from the number of atoms to the weight is here involved. Thus

$$a_k = a_{Ra}\,(T_{Ra}/T_k)\,(A_{Ra}/A_k)$$

where a_{Ra}, T_{Ra}, and A_{Ra} are the specific radiation, half-value period, and the atomic weight of radium; a_k, T_k, and A_k are the corresponding values for potassium. For radium an analogous formula for the radiation of the plane-parallel layer of the Earth's crust is valid and μ can be replaced by the value 0.112 cm^{-1} (assuming an average density of the Earth's crust of 2.5) and ρ by 10^{-12}g cm^{-3} which is the average content of radium in the Earth's crust. From the comparison of J_K/J_{Ra} the ratio 8.7 results, that is, the ionisation above the oceans would have to be on the average nine times higher than that above the Continent. The two reasons why this is not the case are (*a*) it is not the potassium itself which is radioactive but rather its isotop, which accompanies the potassium but in a much lower concentration than the potassium, and (*b*) the half-value period of potassium is longer than stated by Lawson, both conditions being connected by a common law.

The experimental results obtained during the flight to the Northland (Lenin Land) and during the flight to the Pole (Figs. 2 and 3) do not indicate at all any influence of radiation coming from below and contrasted with the graphs obtained over the Continent they show a variation with height of the ionisation in a closed vessel even in the interval 0 to 1000 meters above sea-level. After subtracting the spontaneous activity of the electrometer (2.5 J) from the ordinates of the two graphs there is found for the height of 1000 meters the value of penetrating radiation 3.2 J; for the average height of 400 m the value is 1.5 J, at sea-level (observation on the pack-ice) the value is about 0.4 J. The value obtained for 1000 meters agrees approximately with values observed at the same height in other latitudes.[32]

If we calculate, from the values obtained in the polar zone at sea-level and at 1000 meters above sea-level, the average absorption-coefficient by a simple equation for zenith incidence of rays, we get $\mu/\rho = 0.0161$ $cm^2\ g^{-1}$ as against the value of the γ-rays of radium C, $\mu/\rho = 0.036$ $cm^2\ g^{-1}$.

As resumé of the researches into the penetrating radiation in the polar zone it may be said that the existence has been proved of a penetrating radiation harder than the *efficient* γ-radiation of radium C, of an average absorption-coefficient $\mu/\rho = 0.0161$ $cm^2\ g^{-1}$, and of an intensity increasing with the height. This radiation has an intensity corresponding with the intensity of the penetrating radiation at other latitudes. The increase of intensity which would

[31] *Nature*, v. 117, 1926 (620).

[32] See *e. g.* ANGENHEISTER, *loc. cit.*, p. 495.

correspond with the theory[33] that this radiation is a secondary effect produced by the cathode rays of high speed, coming from the Sun and concentrated in the zone of the Earth's magnetic poles, has not been found. As regards the flight above Central Europe it must be emphasized that, except the approximate constancy of ionisation in a closed vessel for heights between 300 and 1000 meters, no increase of ionisation was noticed when the airship flew through a storm at about 6 P. M. on April 15.

§2. *Ionic content and electric conductivity of atmosphere*—The Gerdien aspirator worked satisfactorily only during the flight to the North Pole and the values obtained by it are partly shown in Table 4 and partly in Figure 11. In the graph the sums of the number of positive and negative ions are plotted as ordinates.

In general, the curve has a course parallel to the ionisation-curve in a closed vessel showing that the ionisation of the atmosphere in the arctic zone is caused by the penetrating radiation of the atmosphere. The ionic content on the average is twice as large as in lower latitudes, the conductivity however being higher by a slight amount only, and thus according to the formula $\lambda_{\pm} = \epsilon n_{\pm}\ k_{\pm}$ (where $\epsilon =$ electronic charge $= 4.77 \times 10^{-10}$ ESU, $n_{\pm} =$ the number of positive or negative ions, and $k_{\pm} =$ their mobility) the mobility obtained has a value usually lower than 1 cm/sec per volt/cm. A natural explanation of this lower mobility may be looked for in the foggy weather prevailing during the greater part of the two polar flights; in addition to this, it is further possible that by the recombination of ions with the microscopic ice-crystals contained in the air, their mobility is decreased. The higher ionisation of the atmosphere here may be clearly explained by its purity; it is therefore poor in condensation-nuclei and thus also in large or Langevin ions. The values obtained for the electric conductivity are in good accord with the values obtained by Malmgren[34] during the polar flight of the airship *Norge* in 1926.

§3. *Potential gradient of atmosphere*—For the reasons explained in the first part of this paper the values obtained have no absolute importance and also the relative comparison is difficult in view of the variability of the electric charge of the airship depending as it does on the number of revolutions of the motors and the intensity of ventilation of the airship-surface as well as on the space-charge of the atmosphere. For these reasons the values obtained are not reproduced here, but it may be stated safely that the potential gradient of the atmosphere is of the same order in the arctic zones as above the Continent.

The most usual value above Central Europe when the sky was clear and the average height was 400 meters above the Earth amounted to +30 volts (relative value measured); the average value in the arctic regions under the same conditions amounted to +25

[33] Hess, Die elektrische Leitfähigkeit der Atmosphäre, p. 126.

[34] Malmgren et Běhounek, *C. R. Acad. sci.*, *Paris*, v. 184, 1927 (1185).

volts. If we compare with this result the values obtained for the electric conductivity of the atmosphere (Table 4), we get, for the density of vertical electric current of atmosphere in the arctic regions, a magnitude of the same order as above the Continent at more southerly latitudes, for example, 10^{-16} ampere per square centimeter.

The potential gradient decreased with the height in accordance with the measurements of other observers. At the time when the airship approached the stormy zone (see Table 1) above Central Europe the potential gradient showed an abnormally high value of 150 to more than 300 volts, even when at a distance of 20 km from the center of the electric discharges. As suggested by Professor Pontremoli it would be easily possible to construct a simple apparatus,[35] depending on measurements of potential gradient, which would amplify the values obtained by means of a radio valve and would transmit them to a milliammeter, by the reading of which the commander of the airship could ascertain the safety of the air-zone from the electrical point of view.

§4. *Radioactivity of atmosphere*—The values obtained by measuring of the activity of the tin foils were converted to the corresponding emanation-content per cc and are shown in Tables 1 to 3.[36] From Table 1, when the airship moved mostly in heights greater than 1000 meters, a decrease of radium emanation with height is clearly evident and therefore also its earthly origin. The value obtained in the stormy zone at a height between 1500 and 1200 meters is the lowest and is even less than the value obtained at the height of 1950 meters which can be explained by the lack of vertical air-streams and therefore by the insufficient mixing of the lower air-layers containing the emanation, with the upper layers poor in emanation. The measurements made above the shores of Sweden (Table 2) give generally a lower value than the measurements above central Europe although the height of the airship was on the average much greater in the latter case. This is apparently due to the influence of the proximity of the sea, with the atmosphere over it poor in radioactive products. Very striking are the decrease of the emanation-content after the start from Vadsö, above the Spitsbergen Sea, and the regular decrease of this element with the gradually increasing distance from the Continent. In spite of this the values measured here are still higher than those obtained during the Polar flight to Lenin Land where an almost absolute lack of radioactive products was found, with the exception of single values measured above the open sea which however are always 100 times lower on the average than the values measured on the Continent. The proximity of Franz Josef Land and Lenin Land had apparently no influence upon the radioactivity of the atmosphere; this may be easily explained by the

[35]Similar to the installation used by Idrac; see *C. R. Acad. sci., Paris*, v. 182, 1926 (1634).

[36]The foils containing radioactive atoms collected during the last flight (Greenland to North Pole to Spitsbergen) were destroyed when the airship was wrecked

snow-and-ice cover of these lands which makes any diffusion of emanation from the capillaries of the frozen ground impossible. Only in the neighborhood of Novaya Zemlya may a certain increase of the emanation-content be noticed though even in this case the values obtained are much lower than the average value 10^{-16} Curie per cc regularly obtained during measurements at southerly latitudes; it may be more of continental origin than from Novaya Zemlya. A slight increase of the activity of the atmosphere may be noted also in the neighborhood of Spitsbergen where the mountain slopes were already partly freed from snow so that a certain diffusion of emanation into the atmosphere was possible, and in the given case its determination was made possible partly by the fact that there was no wind and partly by the sensitiveness of the method used.

The results obtained for the radioactivity of the atmosphere are proofs of the earthly origin of emanation, the concentration of which decreases with the height as has been aready ascertained by Wigand,[37] and also with the distance of mainland.

The researches contained in this paper were made with the collaboration of our two comrades, Professor F. Malmgren and Professor A. Pontremoli, who met their tragic death during the Expedition. To these comrades who are enshrined in our memory we are deeply indebted. We are also obliged to General U. Nobile, who invited us to participate in the scientific collaboration of the expedition and who did his best in supporting us in our endeavors as well as to the Czechoslovak Ministry of Public Works and Education which also helped financially. Also the chemist of the Radiologic Institute of Prague, V. Matula, should have our best thanks for carefully preparing the polonium-collectors.

TABLE 1—*Results during flight from Milan to Stolp*

Date	No.	Time (E.C.T.)		Altitude above sea-level	Geographic position Lat. north		Geographic position Long. east		J	Radium-emanation	Temperature	Rel. humidity	Remarks
1928		*h*	*m*	*meters*	°	′	°	′		10^{-19}*Curie/cc*	°*C*	*per cent*	
Apr. 15	1	3	30	700	45	27	10	10	5.2	420	10 to 12.5	68 to 74	High clouds
	2	6	00	1250	45	27	12	16	5.1	250	6.5 to 10	71 to 77	Over Adriatic Sea
	3	8	30	1950	46	00	14	40	5.9	86	4 to 8.5	78 to 92	Low clouds; strong w storm
	4	11	30	1650	47	13	16	32	5.7	75	5 to 15	50 to 92	Strong wind
	5	14	30	1200	48	12	16	18	3.7	93	6 to 9	20 to 70	Rain lasting 30 minu
	6	16	00	1240	49	11	16	30	4.3	48	6 to 9	20 to 75	Strong wind
	7	17	30	1500	50	05	14	42	5.2	39	3.5 to 9	....	Storm and lightning 30 minutes
	8	20	00	1200	50	18	18	38	4.9	228	4 to 8	70 to 87	High clouds; strong w
	9	22	30	1200	50	15	19	00	4.9	52	......	....	
Apr. 16	10	0	30	1100	50	41	17	55	3.8	146	......	....	

[37] WIGAND, *loc. cit.*

TABLE 2—*Results during flight from Stolp to Kings Bay*

ate	No.	Time (E.C.T.)	Altitude above sea-level	Geographic position Lat. north	Geographic position Long. east	J	Radium-emanation	Temperature	Rel. humidity	Remarks
28		h m	meters	° ′	° ′		10^{-19} Curie/cc	°C	per cent	
y 3	1	4 30	500	54 35	16 52	4.6	180	2 to 3.5	70 to 85	Above Baltic Sea
	2	6 30	500	56 09	15 35	4.7	240	3 to 6	75 to 85	Above Continent from 6^h 35^m to 8^h 36^m
	3	8 30	550	57 16	16 29	4.4	164	2.5 to 5	47 to 80	Sea and islands
	4	10 30	300	57 24	17 40	4.6	120	4.5 to 4.5	40 to 70	Sea and islands
	5	12 30	400	59 20	18 03	4.7	420	4 to 8	37 to 65	Above Stockholm
	6	15 00	225	61 03	19 38	4.5	100	2 to 5.5	65 to 82	Open sea
	7	17 30	275	62 35	20 41	4.6	210	2.5 to 7.0	48 to 80	The first quarter of the flight above the ocean, the rest above the Continent
	8	19 30	425	62 41	23 17	4.5	280	5 to 8.5	45 to 58	Above the Continent
	9	21 30	360	63 45	23 08	4.5	74	5 to 7	47 to 55	Near shore above sea
	10	23 30	375	64 39	24 14	4.3	60	5 to 6.5	45 to 55	Above sea about 30 km from the shore
ay 4	11	2 00	450	66 03	24 56	4.7	80	4 to 6.5	40 to 70	Open sea
	12	4 30	770	67 24	26 37	4.8	54	0.5 to 4.0	70 to 90	Above Continent
	13	6 30	900	68 29	27 27	4.5	48	−1 to 0	90to100	Above Continent
	14	8 30	700	68 54	28 45	4.9	46	−2.5 to 0.5	92to100	Above Continent
	15	10 15	30	70 05	29 44	5.7	116	−3.0 to 0.5	92to100	Airship anchored to mast on seashore at Vadsö; rain from 13^h to 15^h
	16	13 00	30	70 05	29 44	5.2	...	1 to 3	....	
	17	16 40	30	70 05	29 44	5.8	...	1 to 3	....	
	18	22 20	30	70 05	29 44	5.1	...	1 to 3	....	
ay 5	19	3 30	30	70 05	29 44	5.8	...	1 to 3	....	High clouds and strong western wind 3^h 30^m to 7^h 40^m
	20	5 30	30	70 05	29 44	5.1	...	1 to 3	....	
	21	7 40	30	70 05	29 44	5.3	...	1 to 3	....	
	22	9 40	30	70 05	29 44	5.4	...	1 to 3	....	
	23	11 50	30	70 05	29 44	5.3	...	1 to 3	....	
	24	14 00	30	70 05	29 44	5.5	...	1 to 3	....	
	25	17 30	30	70 05	29 44	5.2	...	1 to 3	....	
	26	20 20	30	70 05	29 44	5.2	...	1 to 3	....	
	27	23 00	450	70 32	30 40	3.7	84	−3 to −5.5	65 to 85	Over sea; fog round airship from 23^h 15^m to 23^h 55^m
ay 6	28	1 20	400	71 52	26 00	4.7	24	−5 to −7	87 to 97	Open sea
	29	3 30	500	73 09	22 29	4.7	1	−6.5 to −8.5	80 to 96	Open sea; fog from 2^h to 3^h
	30	6 00	350	74 30	19 20	4.3	8	−9 to −10	72 to 85	Drift-ice
	31	7 30	325	76 00	17 15	4.1	12	−9 to −11	72 to 77	Drift-ice
	32	9 30	450	77 20	14 00	4.1	18	−8 to −11	....	Open sea near Spitzbergen

TABLE 3—*Results during flight from Kings Bay to North Land (Lenin Land)*

Date	No.	Time (G.M.T.)	Altitude above sea-level	Geographic position Lat. north	Geographic position Long. east	J	Radium-emanation	Temperature	Rel. humidity	Remarks
1928		h m	*meters*	° ′	° ′		10^{-19} *Curie/cc*	°C	*per cent*	
May 15	1	12 30	0	78 55	12 00	3.9	. .	+0.8	72	Measured in hangar Kings Bay
	2	14 30	640	79 40	10 47	4.3	16	−1.7	(60)	Near shore of Spi bergen; open sea
	3	16 30	750	80 16	17 33	4.5	18	− 3.3	77	Near shore of Spi bergen; open sea
	4	18 30	500	80 43	23 50	4.1	4	. . . . .	. .	Above pack-ice from 1 25^m
	5	20 30	225	81 03	30 26	3.9	1	− 7.1	92	Above pack-ice
	6	22 30	275	81 18	36 55	4.3	1	−10.1	86	Above pack-ice
May 16	7	0 30	325	81 27	41 16	4.2	1	−13	90	Near Franz Josef La
	8	2 30	500	80 56	47 32	4.7	1	−16.3	89	Near Franz Josef La
	9	5 00	500	81 19	52 09	4.7	1	−14.1	90	Near Franz Josef La
	10	7 30	425	81 52	56 16	4.2	4	−13.4	62	Near Franz Josef Lan open sea and drift-i from 6^h 43^m to 10^h
	11	10 00	325	82 00	62 05	3.8	2	−14.2	36	Above pack-ice
	12	13 00	275	81 28	70 00	4.4	1	−17.9	92	Above pack-ice
	13	15 30	325	80 40	77 06	4.1	1	−17.7	90	Above pack-ice
	14	17 30	400	79 56	82 26	4.2	2	−16.8	94	Above pack-ice
	15	20 30	375	79 26	87 52	4.4	2	−15.7	93	Above pack-ice
	16	23 30	450	79 10	90 30	4.5	6	−12.9	94	Drift-ice
May 17	17	1 30	525	78 21	81 05	4.3	2	−13.9	96	Above pack-ice
	18	3 30	450	77 13	72 30	4.5	2	−13.7	95	Above pack-ice
	19	5 30	600	76 38	66 45	4.3	12	−16.9	90	Above the land (Nova Zemlya)
	20	7 30	1400	76 32	62 52	5.7	8	−17.0	88	Above the land (Nova Zemlya)
	21	9 30	600	76 39	59 18	3.9	3	−16.8	90	Above pack-ice fro 8^h 35^m
	22	11 30	450	77 02	56 91	3.7	5	−11.9	87	Drift-ice
	23	13 30	525	77 25	53 00	4.3	1	−12.1	. .	Above clouds.
	24	15 30	825	77 48	49 50	5.2	1	−12.8	. .	Pack-ice
	25	17 30	375	78 11	46 42	3.9	1	−11.8	. .	Pack-ice
	26	19 30	350	78 34	43 32	4.3	1	−14.9	96	High clouds
	27	21 30	350	78 57	39 33	4.0	1	−13.9	91	Fog; open sea and dri ice
	28	24 00	300	79 26	35 11	4.3	9	− 9.0	97	High clouds; open s and drift-ice
May 18	29	2 30	400	79 57	30 40	4.9	6	− 6.3	97	High clouds; open s and drift-ice
	30	4 30	1000	80 15	27 23	5.7	12	− 9.9	58	Spitzbergen; airsh above ice-berg Lei near shore (sea froze

Note—All measurements contained in Table 3 were made by A. Pontremoli and F. Malmgren.

TABLE 4—*Results during flight from Spitzbergen to Greenland and North Pole*

Date	No.	Time (G.M.T.)		Altitude above sea-level	J	Ionic content		Conductivity		Ionic mobility		Remarks
						n+	n−	λ+	λ−	k+	k−	
1928		h	m	meters		cm^{-3}		10^{-4} ESU		$cm^2volt^{-1}sec^{-1}$		
May 23	1	3	30	400	...	1420	1200	2.0	1.9	1.0	1.1	Near Kings Bay; above the open sea
	2	5	00	400	3.4	1400	1520	2.2	2.6	1.1	1.2	Near shore; above sea
	3	6	30	600	...	1750	1600	2.5	2.5	1.0	1.1	Above the fog
	4	7	00	600	4.8	....	....	...	...	....	....	Partly above fog; partly in fog
	5	8	30	600	...	1850	1400	2.5	2.0	0.95	1.0	Above the fog
	6	9	00	600	4.5	....	....	...	...	....	....	Above the fog
	7	10	00	600	...	1320	1430	1.5	2.0	0.80	1.0	Above the fog
	8	11	00	600	4.3	....	....	...	...	....	....	Above the fog
	9	12	00	500	...	1520	1280	2.1	1.6	0.95	0.90	Above the fog
	10	13	00	500	4.0	1340	1160	1.5	1.7	0.80	1.0	Above pack-ice (clear weather)
	11	14	00	500	...	1240	1100	2.0	1.9	1.1	1.2	Above pack-ice (clear weather)
	12	15	30	500	4.4	1150	1050	1.7	1.8	1.0	1.2	Above pack-ice (clear weather)
	13	16	30	500	...	1030	1000	1.6	1.6	1.1	1.1	Near the Peary Land shores (Greenland)
	14	17	30	500	4.5	....	....	...	...	....	....	Near the Peary Land shores (Greenland)
	15	18	30	500	...	1310	1210	1.7	1.6	0.90	0.90	Above the pack-ice
	16	19	30	500	4.3	....	....	...	...	....	....	Above the pack-ice
	17	21	00	500	...	1420	1400	1.7	1.8	0.85	0.90	Above the fog
	18	21	30	500	4.1	....	....	...	...	....	....	Above the fog
	19	23	00	400	...	1770	1450	2.3	2.0	0.90	0.95	Above the fog, about 30 km from the North Pole
	20	24	00	350	4.5	....	....	...	...	....	....	Above the North Pole
May 24	21	2	00	1000	5.4	2400	2230	2.6	2.2	0.75	0.70	Above the fog
	22	3	30	800	...	1600	1820	2.1	2.5	0.90	0.95	Above the fog
	23	4	00	700	4.8	....	....	...	...	....	....	Above the fog
	24	5	00	500	...	1840	1770	2.6	2.4	1.0	0.95	Above the fog
	25	7	00	500	...	1950	1720	2.5	2.3	0.90	0.95	Above the fog, high clouds
	26	7	30	400	4.3	....	....	...	...	....	....	Above the fog; high clouds
	27	8	00	400	...	2050	1800	2.6	2.3	0.90	0.90	Above the fog; high clouds
	28	9	00	400	...	1780	1520	1.7	2.0	0.65	0.90	In the fog
	29	9	30	400	4.1	....	....	...	...	....	....	In the fog
	30	10	00	400	...	1480	1530	1.3	1.4	0.60	0.65	In the fog
	31	11	00	400	3.7	....	....	...	...	....	....	Above the fog
	32	13	00	400	...	1840	1680	2.6	2.6	1.0	1.1	Above pack-ice, strong SW wind
	33	13	30	400	4.1	....	....	...	...	....	....	Above pack-ice, strong SW wind
	34	14	00	400	...	910	1000	1.4	1.7	1.1	1.2	Above pack-ice; strong SW wind
	35	16	30	400	3.9	....	....	...	...	....	....	Above pack-ice; strong SW wind
	36	19	00	400	4.0	....	....	...	...	....	....	Above pack-ice; strong SW wind
	37	21	30	400	4.0	....	....	...	...	....	....	In the fog, strong WSW wind
	38	23	30	400	4.0	....	....	...	...	....	....	In the fog, strong WSW wind
May 25	39	1	30	400	3.9	....	....	...	...	....	....	In the fog, strong WSW wind
	40	3	30	400	3.8	....	....	...	...	....	....	In the fog, strong WSW wind
	41	6	00	500	4.6	....	....	...	...	....	....	Light fog around airship; strong WSW wind
	42	8	00	200	3.9	....	....	...	...	....	....	Light fog around airship; strong WSW wind

NOTES—(1) Measurements Nos. 1 to 14 were made between 79° and 84° north latitude and between 11° east and 27° west longitude; measurements Nos. 15 to 19 were made between 84° north and the North Pole along the meridian 27° west.
(2) Measurements Nos. 21 to 42 were made between the North Pole and 82° north latitude and between 20° to 30° east longitude.
(3) Minimum temperature during the whole flight was—12°C, the maximum—2°C.
(4) Measurement of ionic-content and of conductivity was stopped on May 24 at 14h as the amber insulator was constantly damp in view of fog around the airship.

TABLE 5—*Ionisation in a closed vessel on the pack-ice*

Date	No.	Geographic position		Time (G.M.T.)	*J*
		Lat. north	Long. east		
		° ′	° ′	h m	
1928					
June 6	1	From 80 37	From 26 50	15 30	3.0
	2	to 80 30	to 28 00	17 00	2.9
	3			18 30	2.9
June 8	4	80 30	28 00	19 00	3.0
June 9	5	From 80 30	From 28 00	2 30	2.5
	6	to 80 37	to 27 00	3 30	2.5
	7			4 30	3.1
	8			8 00	3.2
	9			12 00	2.6
	10			13 00	3.1
	11			15 30	3.2
	12			18 00	2.8
	13			19 00	3.1
	14			20 30	3.0
	15			22 00	2.8
June 10	16	80 37	27 00	23 30	3.3
June 11	17	80 37	27 00	0 30	3.4
	18			9 00	3.3
	19			10 00	3.3
	20			11 00	3.1
	21			12 00	3.1

NOTE—Temperature between —6° and —2°C.

STATE RADIOLOGICAL INSTITUTE,
Prague, April, 1929

EIN TRANSPORTABLES ELEKTRISCHES MAGNETOMETER

Von W. Uljanin

Einleitung

Vor vielen Jahren habe ich[1] eine elektrische Methode zur Bestimmung der Horizontalintensität des Erdmagnetismus angegeben, welche an einem provisorischen, mehrmals umgebauten Apparate am Kasaner Magnetischen Observatorium geprüft wurde. Damals habe ich ein projektiertes transportables Magnetometer beschrieben, welches äusserer Umstände wegen lange Zeit nicht ausgeführt werden konnte. Erst im Jahre 1926 wurden von der Tatarischen Regierung in Kasan die nötigen Geldmittel bewilligt, so dass an die Herstellung des Instrumentes geschritten werden konnte. Das Magnetometer wurde nach meinen Zeichnungen und Beschreibungen von der Firma Prof. Dr. Edelmann und Sohn in München gebaut. Die briefliche Verständigung erforderte geraume Zeit und war nicht immer frei von Missverständnissen. Das Instrument erhielt ich erst im Sommer 1927. Es mussten in der hiesigen Universitätswerkstätte einige Umänderungen, hauptsächlich an den Arretiervorrichtungen, vorgenommen und einige Teile, welche aus nicht ganz unmagnetischem Material hergestellt waren, durch neue ersetzt werden, unter anderen sogar der Kupferdämpfer.

Jetzt ist das neue elektrische Magnetometer gebrauchsfertig und hat sich bei eingehender Untersuchung als durchaus praktisch und empfehlenswert erwiesen. Bei der jetzt allgemein vorschreitenden Tendenz, die klassische Gauss-Lamont'sche Methode durch die elektrische zu ersetzen infolge ihrer anerkannten Vorzüge, ist die Beschreibung dieses erprobten transportablen elektrischen Magnetometers nicht überflüssig.

An dieser Stelle muss ich erwähnen, dass der für das Instrument notwendige Teilkreis auf Dreifuss vom Department of Terrestrial Magnetism der Carnegie Institution in Washington dem Kasaner Magnetischen Observatorium unentgeltlich übergeben wurde. Dies ist einer jener vorzüglichen Teilkreise von 11 cm Durchmesser mit Noniusablesung auf 1′, welche zu dem weltbekannten Universal-Magnetometer der Carnegie Institution gehören. Ich halte es für meine Pflicht, im Namen des Kasaner Magnetischen Observatoriums dem Direktor des Department of Terrestrial Magnetism Dr. L. A. Bauer meinen aufrichtigsten Dank für diese wertvolle Unterstützung auszudrücken. Schon früher wurde ich mehrere Male in entgegekommendster Weise von Dr. L. A. Bauer bei meiner Arbeit unterstützt, unter anderem durch unentgeltliche Zusendung von zwei Weston Standard-Elemente, welche zu der hier verwendeten Methode gebraucht werden.

[1] W. Uljanin, Recueil de Géophysique, v. 2, 1915 (51); *Terr. Mag.*, v. 24, 1919 (118-131).

Beschreibung des Instrumentes[2]

Der Körper des Magnetometers besteht aus einem gegossenen dickwandigen Messingzylinder mit zwei eingedrehten Nuten, in welche die Ablenkungsspulen aufgewickelt sind. Die Anordnung ist die von Helmholtz angegebene zur Erlangung eines möglichst homogenen Magnetfeldes im Zentrum, nämlich die Entfernung zwischen den beiden Spulen ist gleich ihrem Radius und beträgt 5 cm. In diese beiden 1 cm breiten Nuten sind je 2800 Windungen emaillierten Drahtes von 0.18 mm aufgewickelt. Jede Spule hat 533 Ohm Widerstand. Die fertig gewickelten Spulen wurden mit Schellacklösung begossen und im Vakuum getrocknet, so dass sie in festem Schellack eingebettet sind. Ein zweites Paar kleinerer Spulen ("Galvanometerspulen") von zusammen 300 Ohm Widerstand sind in nächster Nähe des Magneten angebracht und ersetzen ein empfindliches Nullgalvanometer, welches zur genauen Abgleichung des Ablenkungsstromes durch Kompensation eines Normalelementes dient.

Diese von mir angegebene Methode, bei welcher diese inneren Spulen ein besonderes Galvanometer ersetzen, wurde von verschiedenen Forschern[3] angenommen, aber teilweise mit einigen Einschränkungen als minderwertige, nur bei Abwesenheit eines zweiten Beobachters zur gleichzeitigen Ablesung des besonderen Galvanometers. Es gelang mir[4] zu beweisen, dass prinzipiell meine Methode, bei welcher derselbe Magnet zugleich zur Messung der Ablenkung, als auch zur Prüfung der Kompensation des Normalelementes dient, zu keinen Fehlern führen kann und in allen Fällen der des besonderen Galvanometers vorzuziehen ist.

Das ganze Magnetgehänge befindet sich in einer Aufhängeröhre, welche vom Apparat abnehmbar ist. Dieses Gehänge besteht aus einem dünnen Glasstäbchen, welches, mittels angekitteter Muffen, unten einen kleinen angeschraubten Glockenmagneten, oben einen Aluminium-Spiegelhalter und eine Klemmvorrichtung für das extradünne Bronzeband trägt. Die Aufhängeröhre hat in der Höhe des Spiegels ein Spiegelgehäuse mit Fenster und oben einen zentrierbaren Torsionskopf, in welchem sich ein Röhrchen verschieben lässt, das oben eine zweite Klemme für das Aufhängeband trägt. Die untere Hälfte der Aufhängeröhre ist aus Glas und unten durch einen dickwandigen Kupferbecher verschlossen, in welchem der Glockenmagnet mit ziemlich starker Dämpfung schwingt. Nach vielen Versuchen und Abänderungen gelang es eine praktische Arretiervorrichtung für das Magnetgehänge herzustellen. Innerhalb des Kupferdämpfers ist eine Messingplatte vertikal zwischen

[2]Der Verfasser ist gerne bereit, auf Anfrage Auskunft zu geben über die Möglichkeit, das hier beschriebene Magnetometer mit Kompensationsbrücke dem hiesigen Universitätsmechaniker zu bestellen, mit Prüfung und Konstantenbestimmung im hiesigen Magnetischen Observatorium.

[3]N. Watanabe und T. Kawamura, *Jap. J. Astr. Geophys.*, v. 1, 1924 (191-206); Rose und Trubjatchinsky, Kurze Anleitung zur Ausführung magnet. Landesaufnahmen. (russ.) Leningrad, 1928.

[4]W. Uljanin, *Terr. Mag.*, v. 29, 1924 (113).

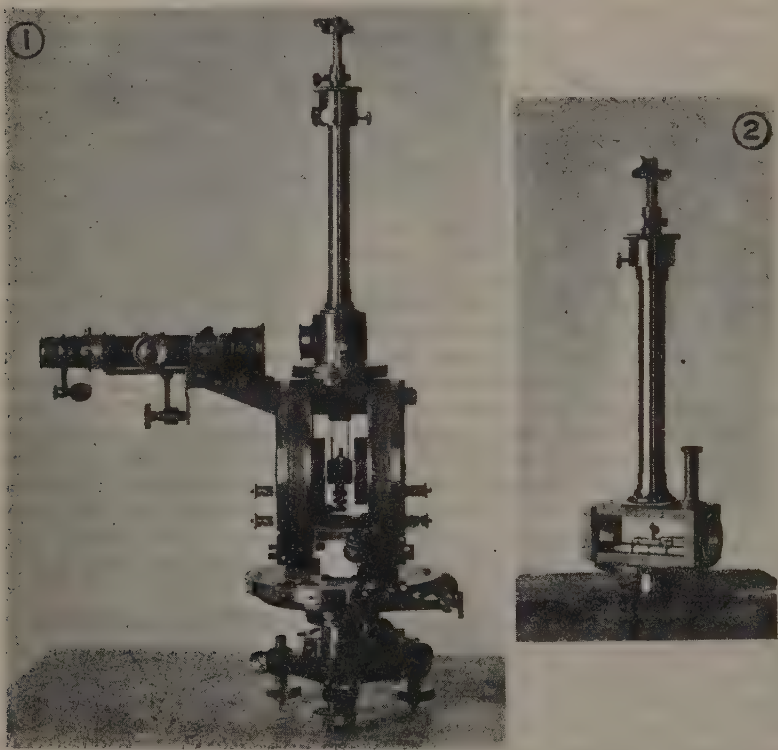
den Schenkeln des Glockenmagneten angebracht, welche ein Umwerfen desselben bei zu starken Ablenkungen verhindert. Diese Platte lässt sich nun mittels einer Schraube von unten parallel selbst heben, bis sie den Magneten zu heben beginnt und dadurch die konusförmige Bronzeband-Klemme an einen entsprechenden federnden Ring andrückt. Dadurch ist das Magnetsystem vollständig fixirt und kann in beliebiger Lage transportirt werden. Zum Transport wird die ganze Aufhängeröhre vom Apparat abgenommen. Damit sie jedesmal wieder ganz genau dieselbe Lage einnimmt, passt sie in eine schwach konische Oeffnung mit breiter Grundplatte oben auf dem Spulenkörper, wobei zwei Stifte in entsprechende Vertiefungen zu stehen kommen. Zwei Schrauben drücken diesen abnehmbaren Teil fest an die Grundplatte.

Das Fernrohr ist ein kleines Autokollimations-Fernrohr, das auf besondere Bestellung von der Firma Casella and Co. in London hergestellt wurde. Anstatt das Reflexionsbild einer äusseren Skala im Fernrohr zu beobachten, wird hier der Mittelstrich einer Okularskala vom Magnetspiegel zurückreflektiert. Vor dem Okular befindet sich eine Glasskala von 40 Teilstrichen mit langem, das ganze Feld durchquerendem Mittelstrich. Auf demselben, etwas unter der Skala ist mit Kanadabalsam ein winziges 1 mm breites totalreflektierendes Prisma angekittet, welches einen von einem drehbaren Aussenspiegel durch eine Seitenöffnung gerichteten Lichtstrahl gegen den Magnetspiegel reflektiert. Im Fernrohr sieht man über der Skala ein helles Rechteck mit schwarzem Strich, welches sich bei Drehung des Magneten auf der Skala verschiebt. Der Vorteil des Spiegelbildes einer inneren Marke besteht darin, dass dabei das Fernrohr mit dem Objektiv dicht an das Spiegelgehäuse gesetzt werden kann, wodurch das ganze Instrument viel kompakter wird.

Wie in meiner Abhandlung vom Jahre 1919 projektiert, wurde das Magnetometer auch zur Bestimmung der Deklination vorgesehen. Zu diesem Zweck lässt sich an Stelle der Röhre mit dem Magnetgehänge ein besonderes Gehäuse mit Aufhängeröhre (Fig. 2) einsetzen, in welchem ein stabförmiger zylindrischer Magnet von 5 cm Länge mit polierter Endfläche in einem besonderen Halter drehbar um seine Axe aufgehängt ist. Für den Transport bleibt der Magnet im Gehäuse, er wird darin bis auf den Boden herabgelassen und da durch eine federnde Arretiervorrichtung festgehalten. Die Torsionslosigkeit des Bronzebändchens wird durch Gleichheit der beiderseitigen Ablenkungen bei Drehung des Torsionskopfes erreicht. Die Richtung des magnetischen Meridians wird, wie üblich, aus zwei Einstellungen des Magneten vor und nach seiner Drehung um 180° um seine Axe abgeleitet. Zum Anvisieren der Mire braucht der Magnet nur etwas heruntergelassen zu werden.

Auch ist der im Projekte vorgesehene Passagespiegel dem Apparate beigegeben. Er ist im allgemeinen demjenigen am alten Kew'schen Magnetometer nachgebildet, jedoch mit verbesserter

Justierungsvorrichtung. Der justierbare Spiegelhalter musste hier in Kasan teilweise abgeändert werden. Besonders waren die horizontalen Axenlager in ihrer Form ganz verfehlt. Nach der Umänderung hat sich die Vorrichtung gut bewährt. Es lässt sich damit genügend genau die Azimutstellung der Sonne bestimmen. Aber leider kann man damit den geographischen Meridian nur bei



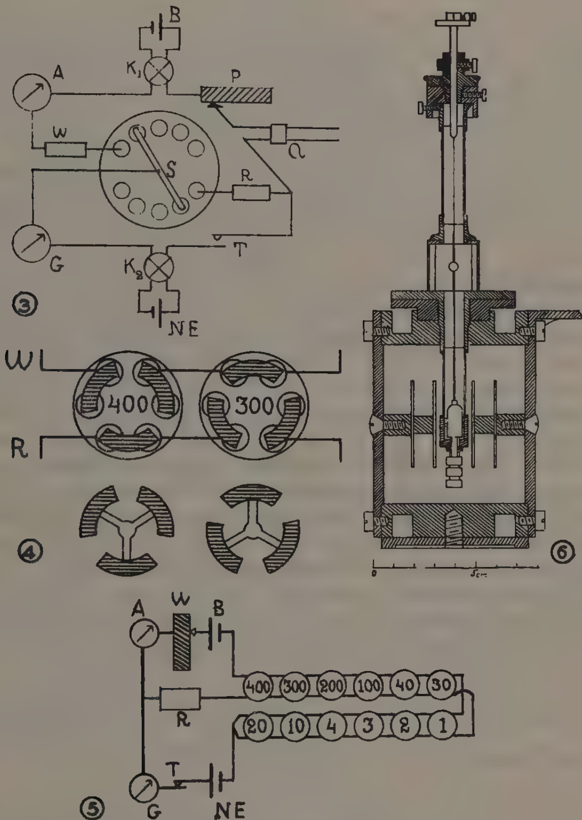
Figs. 1 und 2

genauer Kenntnis der Ortszeit oder der geographischen Länge bestimmen. Dies ist aber in unseren Gegenden selten der Fall bei der noch unvollständigen Landesvermessung. Da ist ein Instrument mit Vertikalkreis nötig, um ausser dem Azimut auch die Höhe der Sonne zu bestimmen, so dass ein kleiner Theodolit mitgenommen werden muss. Im Notfall kann aber auch der gut justierbare Passagespiegel benützt werden, wenn man sich für Nachtbeobachtung am Polarstern entschliessen kann. Dieser Umstände wegen sehe ich von der Beschreibung des Passagespiegels ab, auch die Abbildung des Magnetometers enthält ihn nicht. Da also der Passagespiegel nur in besonderen Fällen ein Instrument

mit vertikalem Kreis ersetzen kann, soll er bei etwaigen weiteren Exemplaren weggelassen werden.

Die Kompensationsbrücke

Die langjährige Anwendung meiner Methode am Kasaner Magnetischen Observatorium hat gezeigt, dass ein Ablenkungswinkel von ca. 70° am passendsten ist. Dabei ist bei grosser Empfindlichkeit die auf den Magneten wirkende Richtungskraft



Figs. 3, 4, 5, und 6

eine noch genügende. Die zur Abgleichung des Ablenkungsstromes nötige Kompensationsbrücke ist derart eingerichtet, dass sie in einem Ablenkungsintervall von 66°—74° ein Horizontalfeld von 0.15—0.19 Gauss zu messen gestattet.

Das Schaltungsschema ist aus der Fig. 3 ersichtlich. Als stromlieferndes Element wird ein kleiner Bleiakkumulator, zur

Strommessung durch Kompensation ein Weston-Normalelement verwendet. Da nun der Akkumulator ungefähr die doppelte Spannung des Normalelementes besitzt, muss zur Kompensation des letzteren der Normalwiderstand R, an den der Normalelementen-Kreis angesetzt ist, ungefähr die Hälfte des Gesamtwiderstandes betragen. Um bei verschiedenem H den dazu passenden Ablenkungsstrom zu erzeugen, können stufenweise je 4 gleiche Zusatzwiderstände w und r resp. in den Hauptstrom- und den Normalelementen-Kreis hinzugefügt werden. Dies geschieht durch den Doppelschalter S.

Es bedeuten: A, Ablenkungsspulen 1066 Ohm und G, Galvanometerspulen 300 Ohm (beide wirken auf denselben Magneten); B, Akkumulator; NE, Normalelement; K u. K Doppelkommutator zum gleichzeitigen Umschalten v. A u. NE; R, Normalwiderstand 2600 Ohm; W, Ballastwiderstand 1350 Ohm; P u. Q, Regulierwiderstände; S, Doppelschalter mit je 4 Zusatzwiderständen zwischen den Kontaktknöpfen $r=w=150$ Ohm; T, Kontaktschlüssel.

Diese Kompensationsbrücke ist für die in meiner früheren Abhandlung als I. bezeichnete Methode des konstanten Normalwiderstandes R bestimmt. Für die II. Methode des konstanten Ablenkungswinkels ist eine andere Brücke nötig, welche es gestattet, ohne den einmal richtig regulierten Hauptstrom zu ändern, den Widerstand R beliebig zu ändern, bis vollständige Kompensation des Normalelementes erreicht ist. Sie besteht aus einem gewöhnlichen Rheostaten mit besonderer Kurbelschaltung (Fig. 4). Je nach der Stellung der Schaltungsscheibe ist der betreffende Widerstand in den Hauptstrom- oder den Normalelementen-Zweig eingeschaltet. Da für einen konstanten Ablenkungswinkel von 70° die Messung von H zwischen 0.15 und 0.19 Gauss einen Widerstand R zwischen 2500 und 3300 Ohm erfordert, besteht die Brücke aus einem auf die angegebene Art umschaltbaren Rheostaten von 12 Widerstandseinheiten vom Gesamtwiderstand 1110 Ohm und einem festen Grundwiderstand von 2500 Ohm. Fig. 5 zeigt das ganze Schaltungsschema. Durch Interpolation lässt sich R bis auf 0.1 Ohm bestimmen, was bei $R=3000$ Ohm $dR/R=3\times10^{-5}$ ergibt.

Bestimmung der Konstanten des Magnetometers

Aus der Formel

$$H=FE/R \sin \alpha$$

ergibt sich der mittlere Fehler von H als Funktion der Fehler der in die Formel eingehenden Grössen

$$dH/H=\pm[(dF/F)^2+(dE/E)^2+(dR/R)^2+(\cot \alpha \, d\alpha)^2]^{1/2}$$

Daraus kann man den zulässigen Fehler der Instrumentalkonstanten F bei gegebenen mittleren Fehlern von R, E, und α berechnen, um H, wie üblich, auf 10^{-4} genau zu sichern. Wir dürfen annehmen: $dR/R=2\times10^{-5}$. Dies ist die im Prüfschein der Physik.-Techn.

Reichsanstalt angegebene relative Genauigkeit eines Präzisions-Stöpselrheostaten von Wolff in Berlin, mit welchem die Normalwiderstände R verglichen wurden. Ferner: $dE/E = 4 \times 10^{-5}$. Dies ist, wie wir im nächsten Abschnitt sehen werden, eine erreichbare Genauigkeit. Endlich enspricht an unserem Instrument der Noniusteilstrich 1′, so dass wir jedenfalls $d\alpha = 0.3'$ setzen dürfen. Dann wird: $\cot \alpha \, d\alpha = \cot 70° \times 0.3' \times \pi/180° = 3 \times 10^{-5}$. Durch Einsetzen aller dieser Grössen in die Formel erhalten wir $dF/F = \pm 8.4 \times 10^{-5}$ eine Genauigkeit, welche am Instrumente, wie die Versuche zeigen, gut erreichbar ist.

Vor allem muss ich hervorheben, dass der Versuch gezeigt hat, dass das beschriebene elektrische Magnetometer ein wirklich transportables Instrument darstellt, welches an jedem neuen Ort in wenigen Minuten gebrauchsfertig aufgestellt werden kann. Die einmal erfolgte Zentrierung des Magneten, welche infolge des geringen Spielraumes zwischen Magnet und Dämpfer etwas mühselig ist, bleibt nach vielmaligem Entfernen und Wiederaufsetzen der Röhre mit dem Magnetgehänge vorzüglich erhalten. Es braucht nur der ganze Apparat nach der vorhandenen Röhrenlibelle genau nivelliert zu werden.

Aus 14 Vergleichungen mit dem Bifilar, dessen Angaben mittels des Universal-Magnetometers No. 22 der Carnegie Institution auf das Amerikanische Standard zurückgeführt sind, wurde die Instrumentalkonstante bestimmt

$$F = 453.97 \pm 0.0035 \text{ und daraus } dF/F = 0.8 \times 10^{-4}$$

Dieses elektrische Magnetometer wurde im Mai d.J. vom Assistenten Puschkin nach Sluzk (Pawlowsk) genommen, um mit ihm einen Vergleich des Kasaner Universalmagnetometers No. 22 mit dem Sluzker Standard auszuführen. Dieser Vergleich stimmte gut überein mit den denselben Zweck verfolgenden Beobachtungen N. Trubjatchinsky's auf dem Kasaner Observatorium im Sommer 1927 mit einem Sluzker elektrischen Magnetometer, welches zur Anwendung meiner Methode aus einem Brunner'schen magnetischen Theodolit umgebaut war. Nach einer brieflichen Mitteilung des Herrn Trubjatchinsky ergaben seine Messungen

Juli 1927 in Kasan	H (Sluzk-Einh.)	0.17192	(Sl.-Kas.) = -13γ
	H (Kasan-Einh.)	0.17205	

Herr Puschkin erhielt

Mai 1929 in Sluzk	H (Sluzk-Einh.)	0.15571	(Sl.-Kas.) = -15γ
	H (Kasan-Einh.)	0.15586	

Der Normalwiderstand R, der in Kasan 2900 Ohm betrug, musste in Sluzk bis zu 3147 Ohm vergrössert werden, um den Ablenkungswinkel von ca. 70° zu bewahren.

Die Normalelemente

Da die elektrische Methode der Messung der Horizontalkomponente auf der genauen Kenntnis der elektromotorischen Kraft des benützten Normalelementes beruht, halte ich es für nicht überflüssig, meine Erfahrungen an verschiedenen Weston-Elementen mitzuteilen.

Als internationales Normal der elektromotorischen Kraft gilt bekantlich das Weston-Kadmiumelement mit überschüssigen Kadmiumsulfat-Kristallen. Dieses Element hat aber einen merklichen Temperaturkoeffizienten. Seine E. K. nimmt um 4 Einheiten der 5 Dezimale ab auf jeden Grad Temperaturzunahme. Da, wie gezeigt wurde, die E. K. des Normalelementes bis auf 4 solche Einheiten bekannt sein muss, um H bis auf 1/100% zu sichern, ist bei diesem Element die Temperaturkorrektion notwendig. Die Temperaturabhängigkeit der E. K. ist aber eine Folge der sich mit der Temperatur ändernden Konzentration. Da nun diese Konzentrationsänderung sehr langsam der Temperatur folgt, ist bei nicht ausserordentlich langsamen Temperaturänderungen die Korrektion sehr unsicher. Dieses Umstandes wegen werden bei der Prüfung der Normalelemente im National Physical Laboratory dieselben, wie im Prüfschein erwähnt ist, 24 Stunden auf konstanter Temperatur gehalten.

Einen etwa 5-mal kleineren Temperaturkoeffizienten besitzen die von der Weston Electrical Instrument Corp. in Newark stammenden "ungesättigten" (bei 4 gesättigten) sogenannten "Standard" Elemente, so dass sie in unserer Praxis ohne Temperaturkorrektion benützt werden können, was besonders bei Feldbeobachtungen von hohem Werte ist. Allerdings herrscht die Ansicht, dass die "ungesättigten" Elemente gegenüber den "gesättigten" den Nachteil besitzen, dass ihre E. K. mit der Zeit abnimmt und zwar verschieden schnell. Ich muss hier ausdrücklich erwähnen, dass ich bei jahrelanger Untersuchung beider Sorten von Weston-Elementen verschiedener Herkunft einen solchen Unterschied nicht finden konnte.

Ich besitze seit 1915 ein "ungesättigtes" Stand.-Element No. 1666 von der European Weston Electrical Instrument Corp., welches damals und in diesem Jahre in Hauptbureau für Mass und Gewicht in Leningrad geprüft wurde. Die beiden Prüfscheine geben folgende Werte der E. K.: 18. März 1915, 1.01893 Volt; 12. April 1929, 1.01853 Volt; also Abnahme um 0.0004 in 14 Jahren, d. h. eine jährliche Abnahme von nur 0.00003. Bedeutend rascher fiel die E. K. zweier amerikanischer "ungesättigter" Elemente der Weston Corp. in Newark, besonders bei einem derselben nahm die E. K. seit 1922 bis auf 1.0162 ab. Eine noch schnellere Abnahme der E. K. fand ich bei einem "gesättigten internationalen" Element der Weston Corp. in Newark nämlich in 2 Jahren bis auf 1.0162, während 2 "gesättigte" Elemente von der Cambridge Instrument Company sich seit 1927 vorzüglich erhalten haben.

Aus einer brieflichen Mitteilung der Weston Electrical Instru-

ment Corp. erfuhr ich, dass es ihnen gelungen sei, durch Versuche festzustellen, dass die mehr oder weniger rasche Abnahme der E. K. eine Folge der durch Erschütterungen beim Transport hervorgerufenen Vermischung der Bestandteile des Elementes sei. Es sei ihnen gelungen, eine Konstruktionsmethode der Normalelemente zu finden, welche diese Fehlerquelle ausschliesst. Die Firma hatte die grosse Freundlichkeit, mir als Ersatz für die früheren unbrauchbar gewordenen zwei neue "Standard" Elemente kostenlos zu schicken. Ich erhielt diese zwei Elemente verkehrt eingepackt (offenbar nach der Revision im Zollamt), so dass sie mit dem Kopf nach unten ankamen. Dass diese unpassende Lage ihnen nicht geschadet hat, beweist die gute Uebereinstimmung ihrer E. K. mit der im Certifikat angegebenen.

Jedenfalls kann ich aus meinen Erfahrungen den Schluss ziehen, dass für die Praxis mit dem elektrischen Magnetometer das "ungesättigte" Weston-Element wegen seines verschwindenden Temperaturkoeffizienten vorzuziehen ist. Allerdings muss jedes zur Verwendung kommendes Element, ob "gesättigt" oder "ungesättigt," von Zeit zu Zeit im Laboratorium mit möglichst vielen anderen verglichen werden.

Kasan, Juni 1929

THE MAGNETIC CHARACTER OF THE YEAR 1928[1]

By G. van Dijk

Forty-one observatories have collaborated in establishing the magnetic character of the year 1928. The lists for Kakioka have no longer been received and at Munich registration of the magnetic variations was interrupted at the beginning of the year on account of the disturbances caused by electric tramlines. Observations are lacking for San Juan for January and September, for Vassouras during the greater part of January and December and for several days in the other months. The Observatory of Buitenzorg was replaced in November by the new observatory at Kuiper, an island in the Bay of Batavia. Thirty-nine stations have sent lists for the entire year. These are: Abinger, Agincourt, Antipolo, Apia, Bochum, Bombay, Buitenzorg-Kuiper, Cheltenham, Coimbra, Copenhagen (Rude Skov), De Bilt, Dehra Dun, Eskdalemuir, Helwan, Honolulu, Huancayo, Karsani, Lerwick, Lukiapang, Meanook, Nantes (Petit-Port), Pavlovsk, Pilar, San Fernando, San Miguel, Seddin, Sitka, Sodankylä, Stonyhurst, Sverdlovsk, Swider, Toolangi, Tortosa, Tsingtao, Tucson, Uccle, Val-Joyeux, Watheroo, and Zouy.

In preparing the annual review the lists of the thirty-nine stations above mentioned have been used. The following table gives the mean character of each day and each month; these numbers have been obtained by dividing the respective sums by 39. There are likewise given the calm and disturbed days of each month and the days recommended for reproduction taken from the quarterly tables.

[1]Abstracted from "Caractère magnétique de l'année 1928," redigé par l'Institut météorologique royal des Pays-Bas, De Bilt, 1929.

Table showing magnetic character for each day of the year 1928

Month	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
January	1.1	0.2	0.1	0.6	0.3	0.3	0.4	0.2	0.4	0.2	0.0	0.0	0.1	0.0	0.3
February	0.7	0.8	0.8	0.7	0.4	0.4	0.5	0.1	0.1	0.2	0.0	0.9	1.0	0.8	0.7
March	0.1	0.0	0.1	0.0	0.0	0.1	0.3	0.1	0.0	0.5	1.8	1.3	1.3	1.2	0.7
April	1.0	0.7	0.9	0.8	0.6	0.8	1.3	0.9	0.7	1.0	0.1	0.1	0.1	0.1	0.7
May	0.1	0.0	0.0	0.3	1.2	0.5	0.6	0.9	0.3	1.4	1.3	1.4	1.1	0.9	1.0
June	0.9	0.8	0.7	0.8	1.1	0.8	1.1	1.0	0.7	0.0	0.1	1.2	1.3	1.1	0.6
July	0.4	1.3	0.9	0.8	0.7	0.7	1.5	2.0	1.2	1.0	0.9	0.6	0.1	0.3	0.1
August	0.7	0.4	0.3	1.1	1.7	1.1	1.1	0.3	0.2	0.1	0.4	1.1	0.6	0.1	0.1
September	0.4	0.8	1.5	0.4	0.7	0.5	1.6	1.5	1.1	0.8	0.7	0.3	0.7	0.9	0.4
October	0.5	1.2	0.8	0.4	1.0	0.8	0.8	0.5	0.0	0.4	0.4	0.5	0.9	0.8	0.7
November	0.6	1.3	1.7	1.1	0.1	0.5	0.4	0.0	0.0	1.2	1.2	0.9	1.6	0.6	1.3
December	0.9	0.4	0.2	0.1	1.2	1.5	0.8	0.5	0.3	0.4	0.9	1.1	0.9	0.7	0.4

Month	Day 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mean
January	0.2	0.1	0.5	0.4	0.8	0.5	0.4	0.8	0.5	0.6	0.5	1.6	1.1	0.9	0.7	0.1	0.44
February	0.7	0.2	0.9	0.9	0.9	1.1	0.5	0.7	0.0	0.9	1.0	0.8	0.7	0.3			0.62
March	0.7	0.6	0.3	0.4	0.3	0.5	0.6	0.9	0.8	0.8	0.5	0.1	0.3	0.2	0.4	0.1	0.48
April	0.9	0.7	0.1	0.6	0.9	1.0	0.5	0.5	0.1	0.1	0.2	0.2	0.0	0.0	0.1		0.52
May	1.1	0.9	1.0	0.8	0.4	0.2	0.1	0.2	0.3	0.3	0.1	1.7	1.9	1.7	0.9	0.8	0.75
June	0.3	0.3	0.3	0.3	0.8	0.6	1.7	1.2	0.9	0.7	0.4	0.3	0.6	0.5	0.4		0.72
July	0.2	0.2	0.7	0.4	0.2	1.0	1.3	0.6	0.7	0.5	0.7	0.6	0.9	0.4	0.2	1.1	0.72
August	0.3	0.3	0.5	0.2	0.1	0.1	0.0	0.8	0.5	0.5	1.7	1.6	0.9	0.3	0.0	0.4	0.56
September	0.0	0.1	1.5	1.4	0.6	0.2	0.9	0.8	1.1	1.6	0.8	0.6	0.1	0.2	0.6		0.75
October	1.0	0.8	2.0	1.2	0.8	0.9	1.1	0.4	1.7	1.8	1.1	1.0	0.3	0.7	0.8	0.6	0.83
November	1.2	1.3	0.8	0.7	0.2	0.1	0.0	0.2	0.8	0.6	0.3	0.4	0.0	0.0	0.4		0.65
December	0.3	0.0	0.3	0.0	0.1	0.8	0.7	0.1	0.7	0.8	0.9	0.3	0.2	0.6	0.4	0.2	0.54

Table showing magnetically calm and most disturbed days for the year 1928

Month	Calm Days						Most Disturbed Days				
January	(0.04)	11,	12,	13,	14,	31	1 (1.1),	23 (0.8),	27 (1.6),	28 (1.1),	29 (0.9)
February	(0.08)	8,	9,	10,	11,	24	13 (1.0),	18 (0.9),	19 (0.9),	21 (1.1),	26 (1.0)
March	(0.03)	2,	4,	5,	9,	31	11 (1.8),	12 (1.3),	13 (1.3),	14 (1.2),	23 (0.9)
April	(0.04)	12,	13,	25,	28,	29	1 (1.0),	7 (1.3),	10 (1.0),	20 (0.9),	21 (1.0)
May	(0.06)	1,	2,	3,	22,	26	10 (1.4),	12 (1.4),	27 (1.7),	28 (1.9),	29 (1.7)
June	(0.18)	10,	11,	16,	17,	27	7 (1.1),	12 (1.2),	13 (1.3),	22 (1.7),	23 (1.2)
July	(0.16)	13,	15,	16,	17,	20	2 (1.3),	7 (1.5),	9 (1.2),	22 (1.3),	31 (1.1)
August	(0.07)	10,	14,	15,	20,	22	4 (1.1),	5 (1.7),	7 (1.1),	26 (1.7),	27 (1.6)
September	(0.13)	12,	16,	17,	21,	28	3 (1.5),	7 (1.6),	8 (1.5),	18 (1.5),	25 (1.6)
October	(0.30)	9,	10,	11,	23,	28	2 (1.2),	19 (1.2),	22 (1.1),	24 (1.7),	25 (1.8)
November	(0.01)	8,	9,	22,	28,	29	2 (1.3),	3 (1.7),	13 (1.6),	15 (1.3),	17 (1.3)
December	(0.06)	4,	17,	19,	20,	23	1 (0.9),	5 (1.2),	6 (1.5),	12 (1.1),	13 (0.9)

Days recommended for reproduction
First selection: July 8; October 18. Second selection: March 11; May 27, 28; August 26; September 7; October 25.

METHOD FOR MEASURING THE SUSCEPTIBILITY OF ROCKS

By J. G. Koenigsberger

Abstract—Lord Kelvin's mathematical method of electrical images applied to a magnet gives the susceptibility of a body having a plane surface placed near the magnet. The different corrections for varying distance, finite surface area, and finite height perpendicular to the surface are discussed. The method is suitable for use in the field with a variometer to determine the susceptibility of samples of rocks. Crystalline schists and other rocks often exhibit a magnetic anisotropy. A provisional scheme for a magnetic-geological classification of rocks based on remanent magnetism is given. The order of magnitude of remanent induced *KF* is compared with present values.

§1. For magnetic observations in the field, it is sometimes advantageous to know the magnetic susceptibility of the neighboring rocks: (1) For a satisfactory interpretation of the results of the local magnetic survey; (2) for selecting an appropriate stone as standard for the magnetic apparatus; (3) for choosing a suitable point for observations in mountainous countries where slopes may produce changes in the magnetic field which depends upon the susceptibility of the rock and the inclination of the slope.[1]

For these purposes there is need of a method to determine a magnetic field not much stronger than that of the Earth, which may be used during field-observations to give in a few minutes a result for fragments of rock taken from the ground. There are good methods for use in the laboratory described by E. Wilson[2] and F. Stutzer.[3]

§2. For use in the field the principle of the electrical (potential) images of Lord Kelvin applied to a magnet may be considered. An approximately plane surface of the material, the susceptibility of which is to be measured, is placed at a distance, a, of 1.5 to 5 cm (according to the susceptibility of the material) from a magnet[4] of length, l, 10 cm and of diameter 3 mm, l being large as compared with a (see Fig. 1). The angular displacement of the magnet produced by the attraction of the image of the magnet in the material is observed on a graduated scale. The attraction is proportional to the difference of the volume-permeability μ', of the body with the plane surface minus μ_0 of the air. The sensitivity in gammas of one scale-division is measured by deflections with a magnet of known magnetic moment. The ponderomotive force exerted by the image on the magnetic mass, m, of the magnet (with the magnetic moment $M=m\, l_1$) is computed to be

$$[(\mu'-\mu_0)/(\mu'+\mu_0)]\ [m^2/4a^2] \ldots\ldots\ldots\ldots\ldots (1)$$

and therefore if $\mu_0=1$, the force and deflections are proportional

[1] *Beitr. Geophysik*, v. 20, 1928 (293).

[2] *Phil. Trans. R. Soc.*, A, v. 219, 1919 (83).

[3] *Metall und Erz*, v. 15, 1918 (1).

[4] The instrument was a vertical-intensity variometer; a dip needle, a horizontal-intensity variometer, a declination-variometer. or some other instrument can also be used in this method.

to $4\pi K'$ since $\mu' = 1 + 4\pi K'$. This was proved experimentally using solutions of Fe_2Cl_6 (ferric chloride) of different known concentrations.[5] The values of K' of the solutions were compared with water for which K' should theoretically be the same as observed in high magnetic fields. It was found that K for the Fe_2Cl_6 solutions is approximately the same as measured in high magnetic fields. Hence the instrument can be calibrated for measurements by using this solution. If the susceptibility of the material is low, the value of K for air at 0° and pressure 760 mm, namely, $K_0 = 3 \times 10^{-8}$, may not be neglected.

§3. Formula (1) given above is true only for an infinite surface of the body and if the body extends infinitely from that surface. For a body with a second nearly plane surface, parallel to the first, at a distance h (see Fig. 1), there is a succession of images; the next image gives a force

$$[(\mu' - \mu_0)/(\mu' + \mu_0)]\ [m/4\ (a+h)^2]$$

The third and fourth images are equal but of opposite sign and hence produce no effect. For $h = 1$ cm it is sufficient to take the

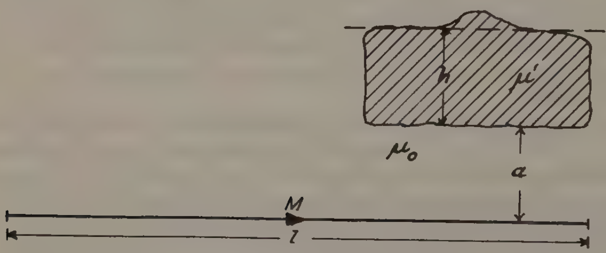


FIG. 1

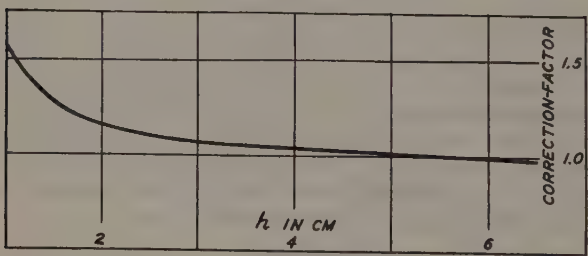


FIG. 2

first and second images. The correction-factor for varying thickness as calculated (see Fig. 2) and proved experimentally is shown by the following table:

[5] The mass-susceptibility, K'', for a solution of p percent is $10^6 \times K'' = 88p - 0.78\ (1-p)$. The density, s, is determined with an areometer; standard tables of s give p; $K' = K''/s$.

Thickness h in cm	Observed scale-reading	Computed scale-reading	Computed correction-factor
1.2	18.5	19.0	0.68
2	22.7	23.6	0.85
3	26.1	25.8	0.93
6	27.8	(27.8)	1.00
∞	....	29.0	1.04

For a plate 6 cm thick, the factor was made equal to 1. The body is also not infinite in the other directions and therefore does not have infinite plane surfaces. The surfaces are limited. Nearly rectangular surfaces were much used. For a length of side of 6 cm, approximately equivalent to a diameter d of 8.3 cm of a circle (see Fig. 4) or $d' = 5.7$ cm, the effect is made equal to 1, if this surface is at a distance of 1.5 cm from the axis of the magnet. For another length or an equivalent d', and the same distance from the magnet, the factor obtained experimentally is shown by Fig. 3. The factor is always the same for the same value of (d'/a). For another a' the reduced d' is $d''a/a'$, if d'' is measured. The contour-line is not of great importance provided the form of the surface is somewhat like that of a square or a rectangle with sides not differing too greatly in length or if it is a part of a circle with its center at O.

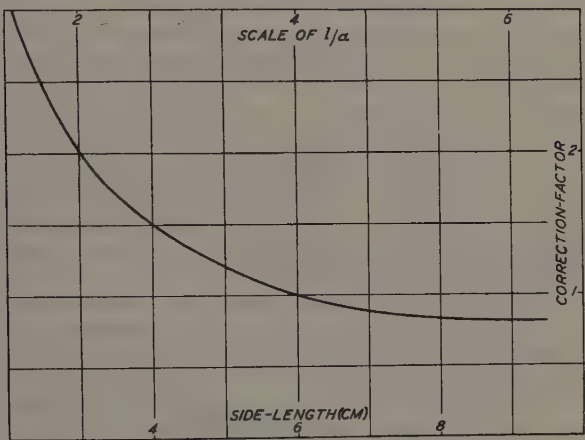


FIG. 3

For the part of a circle of diameter d the equivalent length is approximately $1.36b$ and $d' = b/1.03$ (see Fig. 4). If the area q of this border-surface is irregular it should be measured and in a first approximation the equivalent length is the square root of q. One side of the surface must be vertical to the magnet at a distance of 1.55 cm from the center of the magnet (see Fig. 4), if the magnet is 10 cm long. The magnetism of the needle may be supposed to be concentrated within 5/6 of its length even for this short distance. A wedge composed of a mixture of hydrohaematite

powder and paraffin was moved vertically to the axis with the sharp end always at a vertical distance of 1.5 cm from the horizontal axis of the needle. The greatest deflection was thus obtained at 4.15 cm horizontal distance from the center of the needle. If the distance of the surface of the body, the susceptibility of which is to be measured, from the axis of the needle differed from that used for the solutions, the law of inverse square of the distance *a* can be used, as is shown in the following table:

Distance *a* in cm	Observed scale-reading	Computed scale-reading
0.905	7.6	7.4
1.75	2.0	(2.0)
2.15	1.4	1.32
2.25	1.2	1.20
2.95	0.6	0.70

For rocks of large susceptibility, $K > 10^{-4}$, the distance must be greater than 1.5 cm; for very low susceptibility it may be smaller.

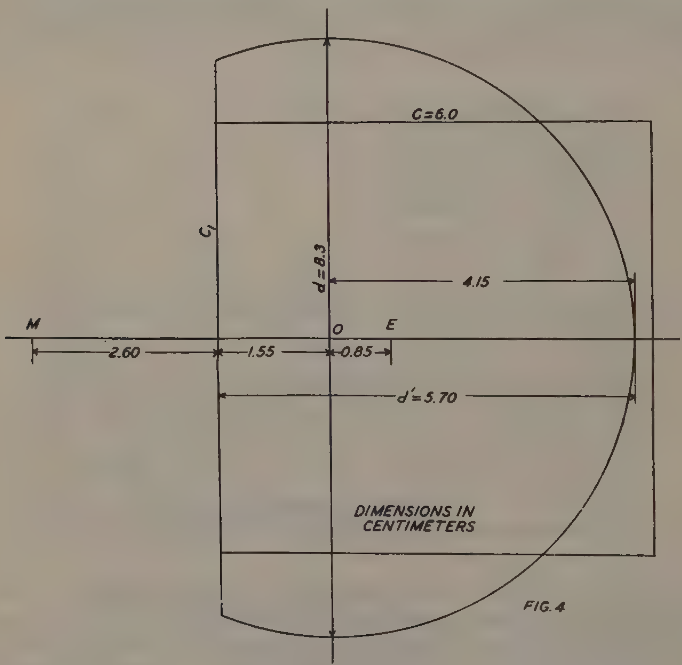


FIG. 4

When the magnetic needle is attracted too strongly it comes too near to the rock and imparts to it immediately a strong remanent magnetism. Accordingly when making comparisons between the specimen and standard solution, it may happen that the magnet will be deflected too near to the surrounding copper tube on which

the plate bearing the rock rests. It is always possible to eliminate a remanent magnetism by turning the rock through 180° and taking the mean of the observed deflections. This procedure may also give accurate values for the relatively weak natural remanent magnetism of many rocks which has been induced by the Earth's field. If the surface of the body is not plane but undulated, an average distance, greater than the normal distance, must be taken into account.

§4. The following example illustrates the way in which observations and calculations were carried out for a granite specimen at Gotthard, Switzerland. A rock fragment was taken from the ground and adjusted a little with the hammer. The undulated side-plane was about 5 by 8 cm; the equivalent length of side was therefore about 6.3 cm. Fig 3 gives a correction-factor of 0.95. The rock was placed upon the plate fixed to the copper tube containing the magnet of a vertical-intensity variometer constructed by the author and used for measuring magnetic profiles on the Gotthard route. The distance of the plane from the magnet was about 1.7 cm taking into account the undulations. Therefore the distance-factor was $(1.7)^2/(1.5)^2=1.28$. The height, h, of the piece was about 5 cm. The correction-factor (see Fig. 2) was 1.08. The mean deflection was 0.60 division. The calibration-value for the Fe_2Cl_6 solution of volume-susceptibility $K'=57\times10^{-6}$ reduced to units of surface area and of height and at a distance of 1.5 cm was 1.50 divisions. Therefore K of the granite was $0.60\times57\times10^{-6}\times 1.28\times0.95\times1.08/1.50=28\times10^{-6}$. The average value of the magnetic field in the material near the plane of the side was about 4 gauss, nearly ten times the vertical component of the Earth's field. The susceptibility of a mass of this granite *in situ* was estimated in another way, namely, by measuring the maximum topographical effects (as to the method see footnote 1) and was found to be 2.5 to 3×10^{-6}, and thus the same as found above.

§5. Observations on about a hundred samples have shown that massive igneous rocks have normally, but not always, magnetic isotropy but that crystalline schists often possess a large magnetic anisotropy. K is larger when the magnetic lines of force of the image are parallel to the plane of schistosity ($K_{\parallel}$) than in any other direction and K is smallest when the lines of force are vertical to the schistosity ($K_{\perp}$). The anisotropy $K_{\parallel}/K_{\perp}$ ranges from 1.05 to 2. Some Alpine gneissic granites have a marked anisotropy and in a lesser degree some igneous rocks. This may be explained by assuming an anisometric distribution of magnetic isotropic minerals or also of anisotropic minerals which have a quite irregular arrangement with respect to their crystallographic orientation. J. Clerk Maxwell (Treatise, §322) has given the theory for an anisotropy of electrical conduction by anisometrical pieces of anisotropic material, with parallel distribution in an infinite isotropic medium. This theory is directly applicable to magnetic induction

§6. A further study of susceptibility has yielded the following provisional scheme for the magnetic induction of rocks in the Earth's field assuming only small changes of the Earth's field in geologic times.

(1) *Remanent magnetized unchanged rocks*—For rock in which magnetization was induced by the Earth's surface magnetic field when there was molten magma near the surface, the induced magnetization at this high temperature becomes, during the cooling, partly or totally remanent at a critical temperature T_c which seems to be about 900° C according to the investigations of Loewinson-Lessing and Turcev.[6] The rock mass remaining in its initial position, the qualitative effect on the Earth's field is the same as by induction. For the case when the susceptibility K_c at this critical temperature T_c is equal to or less than K, the effect of the Earth's field is given by the value of K measured by the method described above. Should K_c be greater than K at the present temperature of the field, the effect of the rock may be larger than that computed from the observed value of K.

(2) *Remanent magnetized broken rocks*—For rock magma which has flown irregularly or has been broken or crushed after cooling below T_c, the greater part of the remanent magnetism remains but is not perceptible in the average effect of great masses.

(3) *Upturned remanent magnetized rocks*—For a rock mass turned as a whole after cooling below T_c, the remanent-magnetism is superposed on the magnetism which is induced.

Which effect is the stronger depends upon the value of the ratio K_c/K. For the hypothesis that the Earth's magnetic field has changed greatly during geological times, it is not possible to distinguish between (1) and (3). There are transitions between these schematic types. A normal remanent magnetism can be found with a sensitive variometer (0.1 scale-division = 0.5 to 1γ) in nearly all eruptive rocks. If this magnetism is put equal to K_cF, where F is the total intensity, the value of K_cF for about one hundred partially cubic samples falls between 0.1 to $3KF$ in present field conditions. As to the accurate direction of F at the time of T_c and K_c, which problem was worked out for basalts, basic effusive rocks, and potteries by Humboldt, Delesse, Melloni, Folgheraiter, Bruhns, David, Mercanton, and especially Chevallier, it may be expected that a new point of view would be given for massive so-called abyssal igneous rocks.

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[6] *C. R. Acad. Sci., Leningrad*, 1927 (61 and 341).

EINIGE WICHTIGE PLANETARE URSACHEN FÜR DIE SCHWANKUNGEN DES ERDMAGNETISMUS IM JAHRE 1927[1]

VON FRANZ GÖSCHL

Der Verlauf der erdmagnetischen Charakterzahlen sei an der Hand von Monatstabellen geschildert. Während im Diagramm für 1926 (Dezembernummer 1928, Seite 219) die hervortretenden Zwei-Tags-Summen als Maxima von 1 bis 16 abgezählt wurden, sind in dieser Tabelle die betreffenden Tageszahlen durch Fettdruck hervorgehoben. Die Minima wurden im Diagramm mit lateinischen Buchstaben von a bis n bezeichnet. Hier sind die entsprechenden Abfolgen, welche in den Drei-Tags-Summen 0.3 nicht überschreiten, in Klammern gesetzt. Links von den Tageszahlen stehen in der Tabelle die fördernden planetaren Einflüsse, rechts die hemmenden. Zum Unterschied von der früheren Darlegung seien diesmal die *einzelnen* positiven und negativen Faktoren nur kurz gestreift; dafür soll die aus der Interferenz sich ergebende Entwicklung eingehender beschrieben sein.

(*A*) Nach der ersten Regel (S. 217, I*a*) müssen die stärksten Maxima auftreten bei der Doppel-Sonnenopposition von Jupiter und Uranus und der damit verbundenen unteren Venus-Sonnenkonjunktion, die alle drei in den September fallen, und zwar muss nach Anmerkung (a) (S. 217) die Hauptwirkung auftreten einerseits bei den gemeinsamen Mondkonjunktionen zu Jupiter und Uranus und andererseits auch bei den Mondbegegnungen zur Venus. Prinzipiell sollten diese Wellen innerhalb der zwischen den Stillständen liegenden Frist sich halten. Die vorhergehenden Stillstände von Uranus und Jupiter erfolgten am 9. bzw. 25. Juli (Zeichen st=stationär). Bald nach der Mondkonjunktion vom 19. erhob sich der Scheitel vom 21. bis 23. Juli; nach jener vom 16. August erschien die hohe Reihe 19.-22.; der Begegnung vom 12. September ging der Scheitel am 9./10. vorher; jene vom 9. Oktober war umhüllt von der langen Reihe der hohen Zahlen 7.-13.; hingegen war am 5./6. November, sowie 3. Dezember die Maximum-Welle unterdrückt, obwohl die Stillstände erst am 20. November, bzw. 10. Dezember, erfolgten. Aehnlich war es auch im Diagramm 1926; die analogen Gründe hiefür werden bei den Hemmungen erwähnt. Weil jedoch Neptun seit seinem, der Sonnen-Opposition 1928 vorhergehenden, Stillstand (2. Dezember) seine Zustrahlung

[1]Bezüglich des gleichnamigen Aufsatzes über 1926, der im vorigen Jahrgang der Zeitschrift erschien, möchten folgende kleine Druckversehen berichtigt werden: Seite 211 Mitte statt Marsdurchgang *AoJ* corrige *AcJ;* Seite 214 Mitte statt Hemmung der Merkur-Venuskonjunktion corrige Merkur-Erdekonjunktion; Seite 218 Zeile 20 von unten statt unterhalb der Schwankungskurve corrige oberhalb; in der 16. Zeile von unten statt "In der zweiten" corrige "In der dritten."

Zum ersten Abschnitt auf S. 216 sei noch eine nachträgliche Bemerkung gestattet: Die durch die geehrte Schriftleitung in dankenswerter Weise besorgte Ergänzung der auf Seite 215 gebrachten Tabelle der Sonnenflecken-Relativzahlen, welche der Verfasser nur in einer provisorischen und teilweise lückenhaften Form zur Verfügung hatte, weist auch für die Mitte vom Dezember noch einen nachträglichen Höchstwert der Sonnentätigkeit auf, als die in der zweiten Novemberhälfte stark erregte Sonnenpartie nach einer Umdrehung wieder zur Beobachtung gelangte.

begann ist der Scheitel bei seiner Mondkonjunktion am 13. Dezember begreiflich. (Vgl. Anmerkung (*a*) S. 217.) Bezüglich der Venus-Welle, die sich wenigstens zwischen den Stillständen (18. August und 30. September) bei ihren Mondbegegnungen zeigen sollte, ist zwar gleich nach der Venus-Mondkonjunktion vom 28. August an den beiden folgenden Tagen der Effekt zu ersehen, hingegen folgen auf jene vom 23. September erst am 25./26. mässig hohe Zahlen nach; dafür kommt wieder ein starker Scheitel bei der folgenden Venus-Mondbegegnung am 21. Oktober. Der Grund für die Septemberhemmung kommt bei der Behandlung der Interferenz zur Sprache.

(Anmerkung: Ein Analogon zu dieser Doppelwelle zeigt das Diagramm 1926 für Januar-Februar, indem einerseits bei den Mondkonjunktionen zum opponierenden Neptun die Maxima 3 und 5 erschienen, andererseits bei den Mondbegegnungen zur Venus die Scheitel 1, eine Erhebung vor 4 und 7 auftauchten.)

Für das erste Halbjahr spielt die Anwendung der III. Regel auf Seite 218 die Hauptrolle. Es standen sich nämlich von der Sonne aus Jupiter und Neptun noch nahe genug einander gegenüber, was aus der Tabelle in der raschen Aufeinanderfolge der Neptun-Sonnenopposition (15. Februar) und Jupiter-Sonnenkonjunktion (1. März) zum Ausdruck kommt. Nun ging aber auch die Venus auf der von der Sonne aus entgegengesetzten Seite kurz vor der Erde durch diese Oppositionslinie. (Von der Sonne aus war die Venus-Neptunopposition am 15. Januar, die Venus-Jupiterkonjunktion am 22. Januar.) Nach der III. Regel (S. 218) "muss die Hauptwirkung auf der Erde dann eintreten, sobald nahe der Sonnenopposition des einen Planeten die Konjunktion der Venus zum anderen erfolgt." Diese (terrestrische) Jupiter-Venuskonjunktion war am 5. Februar, die Neptun-Sonnenopposition am 15. Februar. "Es bilden sich kräftige Wellenscheitel für die Zeitpunkte der Mondkonjunktionen zu dem von der Sonne aus in Opposition tretenden Planeten aus." In unserem Falle müssen es die Mond-Neptunbegegnungen sein. In der Tat hielten sich die hohen Zahlenwerte von da an in der Nähe der geforderten Termine. Im Februar kommen die Höchstwerte am 9./10. zwischen der Erregung (5.) und Mondkonjunktion (16.), wobei am letztgenannten Tage eine nachträgliche Anschwellung erfolgt. Im März hängt sich eine hohe Zahlengruppe unmittelbar an die Mondbegegnung vom 15. an (15.-18.), während die am 9./10. vorhergegangene wohl durch den vorhergehenden Stillstand des Merkur (3.), der am 13. in untere Sonnenbegegnung geriet, geweckt sein dürfte. Im April setzen vor und bei der Mondbegegnung zu Neptun (11.) hohe Zahlen ein, die bald darauf (13.-15.) ein Maximum erreichen. Jener vom 9. Mai geht wegen einer Interferenz der Höchstwert schon am 4./5. voraus, doch steigen bei der Annäherung an die Mondbegegnung die Zahlen nochmals nahe an einen Scheitelwert.

Anmerkung: 1. Im Januar musste die eben geschilderte Einflussnahme erst eingeleitet werden. Die Erde stand (am 3.) im Perihel und konnte daher nicht bloss die Sonnentätigkeit durch Meteoritenzulenkung fördern, sondern auch umgekehrt Sonnenverfehler von Meteoriten,

die von der entgegengesetzten Seite her wegen des nahen Durchzuges der Venus zwischen Sonne und Jupiter herangezogen wurden, sich aneignen. Das musste am besten gelingen bei der Mond-Venuskonjunktion am 4. Januar. Daher erschienen daselbst hohe Zahlen, die zwar am 6. wegen der Mondbegegnung zu Jupiter, der schon nahe der hemmenden Sonnenkonjunktion stand, zurückgingen, aber dann zum Maximum anschwollen. Im Februar fehlte dieser begünstigende Umstand. Nach der Neptun-Sonnenopposition und den vorhergehenden, schon erwähnten Venusstellungen war die Oppositionslinie von Neptun bis Jupiter mit Meteoriten bereichert, von denen die Erde bei den Mondkonjunktionen zu dem auf der gleichen Seite stehenden Neptun am leichtesten Anteile für sich erwerben konnte. Auf dieser Hypothese fusst ja die III. Regel (S. 218).

2. An sich wäre auch die Sonnenopposition des Saturn am 26. Mai ein fördernder Umstand. Weil sie jedoch noch näher an die Hemmungsstelle bei der hel. Länge 270° gerückt ist als 1926, ist sie nach der II. Regel (S. 217 unten), ähnlich wie im Diagramm 1926, eher als Hemmung zu werten. Am leichtesten könnte sie noch fördern beim vorhergehenden Stillstand, weil daselbst die Erde der Hemmungsstelle noch ferner stand. Es könnte das Maximum Ende März, das nach diesem Stillstand (18.) und der Saturn-Mondbegegnung (24.) vom 26. bis 28. erschien, damit in Verbindung stehen; freilich war hiefür auch der nachfolgende Stillstand des Merkur (26.) mitbestimmend.

(*B*) Bezüglich der *Minima* wies das Diagramm 1926 nach der IV. Regel die tiefste Ebbestelle *m* im November auf, veranlasst durch das Zusammenwirken der Saturn-Sonnenkonjunktion und der oberen Sonnenbegegnung der Venus, wobei die flankierenden Mondbegegnungen die tiefen Senkungen l und n hervorriefen. Ein ähnliches Zusammenwirken sehen wir auch für November 1927, insofern als die Saturn-Sonnenkonjunktion vom 3. Dezember und die Mars-Sonnenbegegnung vom 21. Oktober interferieren, was zum niedrigsten Monatsmittel des inzwischen liegenden Novembers beigetragen haben muss. Bezüglich der betreffenden Mondbegegnungen setzte nach jener des Saturn vom 28. Oktober eine lange Reihe von Ruhetagen ein; im November war jene vom Mars und auch die vom Saturn (23., 25.) von je einem Ruhetag begleitet; im Dezember zeigte sich bei der gemeinsamen Mondkonjunktion am 22. eine dreitägige Ruhepause. Wie im Diagramm 1926 die Minima g und h durch Zusammenwirken der Neptun-Sonnenkonjunktion und der oberen Merkur-Sonnenbegegnung entstanden sind, so konzentrierte sich noch viel enger 1927 die Einwirkung der Neptun-Sonnenkonjunktion vom 20. August mit jener der oberen Merkur-Sonnenkonjunktion vom 2. September bei der inzwischen einfallenden Konjunktion zueinander (27. VIII.), wozu sich am Vortage die gemeinsame Mondbegegnung gesellte. Daher die Ruhepause vom 24.-26. VIII.; auch bei der nächsten Neptun-Mondbegegnung am 23. IX. trat eine solche ein. Die Konjunktionshemmungen scheinen etwa 10 Tage vor dem Konjunktionstermin einzusetzen. So erschien im 1. Halbjahr vor der oberen Merkurkonjunktion vom 28. Januar eine Ruhepause vom 20. bis 23. Januar, vor jener am 20. Mai eine solche vom 10.-13. Mai, vor der Jupiter-Sonnenkonjunktion vom 1. März eine dreitägige Ruhe vom 21.-23. Februar, während die Neptun-Sonnenkonjunktion vom 21. März unmittelbar von einer solchen vom 21.-25. begleitet war. Letztgenannte interferierte mit der oberen Merkurbegegnung vom 20. Mai bei der inzwischen am 17. April auftauchenden Uranus-Merkurkonjunktion, woselbst vom 16. bis 22. tiefe Verebbung der Schwankungen erfolgte.

Eine exakte Deutung erfordert noch die Verknüpfung der eben genannten planetaren Hemmungen mit den Hemmungsstellungen bezüglich der *Sonnentätigkeit.* In diese Tabelle sind von den (auf

S. 215 in der Jahrestabelle 1926 angeführten) solaren Hemmungsursachen nur die von der Sonne aus gerechneten Merkur-Venuskonjunktionen aufgenommen. Jene vom 13. Februar war mit 2 positiven Erregungen verknüpft (nämlich den Durchgängen der inneren Planeten zwischen Jupiter und Sonne, die bezüglich Venus unter dem 22. I., seitens Merkur unter dem 5. II. in die Tabelle eingetragen sind) und kommt daher nicht in Betracht. Hingegen stand jene vom 24. Juni weit von solchen Erregungen ab, weshalb sie von einer langen Ruhepause (18.-25.) begleitet war. Von einschneidender Hemmung musste jene vom 17. November sein. Es standen auf der gleichen Seite von der Sonne aus alle 3 innersten Planeten. Gemeinsam hatten Venus und Erde in der 2. Septemberhälfte den Jupiterleitstrahl durchquert; der von der Erde eingefangene Meteoritenschwarm tat sich im höchsten Monatsmittel des Oktober kund. Einige restliche Mengen, die Merkur bei seinem Durchzuge am 2. Oktober näherzog, musste er beim Perihel (14.) der Sonne überstellen; wegen der geringeren Entfernung von der Venus konnte trotz der unteren Merkur-Sonnenkonjunktion vom 10. die Erde ihm nichts nennenswertes abfangen. Daher die scheinbar gegenteilige Äusserung der unteren Merkur-Sonnenkonjunktion, die Dämpfung der Jupiter-Welle und das niedrigste Monatsmittel im November. Deutlich zeigt dieser Umstand, dass eine rein cyklische Methode versagen muss, hingegen nur eine synoptische zum Ziele führt, die ja auch in der praktischen Verwertung der Wetterkarten als einzige sich bewährt.

(*C*) Um im Sinne einer solchen ein kleines Bild der Interferenz der positiven und negativen Faktoren zu verschaffen, sei kurz der wechselnde Gang der erdmagnetischen Charakterzahlen für einen Grossteil des Jahres noch eigens behandelt.

Anmerkung: Im Vergleich zu den unter (*A*) behandelten Mondkonjunktions-*Wellen* bedeuten die Oppositions-*Termine* der äussersten Planeten untergeordnete Momente. Zu den sekundären Förderungen sind gleichfalls die planetaren (von der Erde aus gerechneten) Oppositionen zu rechnen, die bezüglich Merkur, Venus und Mars sämtlich in die Tabelle eingetragen sind. Die von der Erde aus gerechneten planetaren *Konjunktionen* sind *fördernd*, wenn die untere Sonnenbegegnung (bzw. Mars-Sonnenopposition) in der Nähe ist, oder ein ähnlicher Fall wie am 5. Februar eintritt; hingegen *hemmen* sie in der Nähe der oberen Begegnung (bzw. Mars-Sonnenkonjunktion) und zwar mitunter stark, wie bezüglich 17. April und 27. August erwähnt wurde. (Die wenigen im Text gestreiften solaren Erregungen dienen nur der Orientierung.) Als untergeordnete Förderung ist noch Vollmond, als ebensolche Hemmung Neumond und Perihel eingetragen. Die jeweiligen Mondkonjunktionen sind in der Nähe der hemmenden Konstellationen auf der rechten Seite, in der Nähe der fördernden auf der linken eingetragen. Beim Uebergang fehlen die schwächeren.

Diskussion—Unter (*A*) kam zur Sprache, inwiefern durch die Mond-Venuskonjunktion vom 4. Januar in der ersten Dekade eine starke Anschwellung erregt werden musste. Die vom 1. Januar einsetzenden hohen Zahlen werden am 3. durch Erde-Perihel und Neumond gedämpft, am 6. durch die Jupiter-Mondkonjunktion, am 8. durch die Uranus-Mondbegegnung, weshalb 9. 10. niedere Werte erscheinen. Kleiner Schwankungszuwachs ist zu merken bei Mars-Mond (12.) und zwischen Vollmond (17.) und Neptun-Mond (20.). Die starke Wellenzustrahlung seitens Neptun wird durch die Vorhemmung vor der oberen Merkur-Sonnenkonjunktion (28., *Cf.* B) zurückgehalten und gelangt erst

24.-26. zum Durchbruch. Die Venus-Neptungegenstellung vom 30. verhindert ein Minimum am Konjunktionstermin; der Zahlenwert erhebt sich am 29. auf 0.6. Anfangs Februar erzielen die 2 Dämpfungen am 2. eine Senkung, am 3. ein fördernder Umstand eine Hebung und die Dämpfungen vom 3. und 5. wieder Senkung. Insbesondere vereinigt sich am 6./7. die Nachhemmung vom 28. Januar und die Vorhemmung vom 13. Februar zu völliger Ruhe. Dann löst die Gegenspannung vom 7. mit der Mondkonjunktion vom 9. die Erregung vom 5. (sowie 30. I.) aus, im unter (*A*) erwähnten Scheitel 9./10.). Der Einfluss der 3 positiven Faktoren vom 15./16. ist durch die solare Hemmung am 13. herabgemindert (daher niedere Zahlen am 14./15.); insbesondere vereinigen sich 21.-23. die Nachhemmung vom 13. und die Vorhemmung vom 1. März zu totaler Ruhe. Auch Merkur-Perihel mag abgedämpft haben. Am 24. setzt wieder eine Gegenspannung, die jene vom 5. Februar vervollständigt, ein, wozu auch Mond-Saturn am nächsten Tage mithilft, da Saturn am 9. März gleichfalls in eine solche Gegenspannung gerät, weshalb Ende Februar höhere Zahlen auftauchen trotz der unmittelbaren Konjunktionshemmung vom 1. März. Dass am 1. März selber eine so hohe Zahl aufschien, kann wohl nur der Stillstandsnähe des Merkur zugeschrieben werden. Die 3 Dämpfungen vom 3. und 4. verhelfen der Konjunktionshemmung vom 1. zur Geltung; doch lassen 2 fördernde Mondbegegnungen keine Ruhepause aufkommen. Die Marsgegenstellung vom 9. erfolgt gleichzeitig mit seiner Mondkonjunktion (9.), womit die Auslösung für das durch die untere Merkur-Sonnenkonjunktion (13.) geweckte Maximum gegeben ist (9./10.). Um den 11. interferiert die Nachhemmung vom 1. mit der Vorhemmung vom 21., weshalb die Maximumreihe unterbrochen wird, die aber wegen der unter (*A*) besprochenen Neptunwelle bei Neptun-Mond am 15. zum Scheitel 15.-18. sich erhebt, wozu sich am 18. und 20. Förderungen gesellen. Die Konjunktionshemmung vom 21. kann sich in der Ruhepause 21.-24. unmittelbar auswirken, weil keine positive Zulenkung interferiert; dafür ist auch die Nachhemmung Ende März schwächer. Das inzwischen liegende Maximum wurde bereits erörtert. Bezüglich April klärt ein Blick auf die Tabelle über die kleinen Schwankungen der 1. Dekade auf; das Maximum und Minimum in der 2. wurden schon unter (*A*) und (*B*) begründet; die 3. ist beherrscht von einer Gegenspannung (23.), wobei eine betreffende Mondkonjunktion am 20. gerade vorherging, weshalb 23.-25. höhere Zahlen auftauchten. Dann zeigt sich der Einfluss einer dreifachen Dämpfung am 28. in einer dreitägigen Ruhe (26.-28.).[2] Im Mai sind die 3 bisher fördernden Mondbegegnungen einander nahe gerückt. Weil Venus Gegenspannung ausübt (23. IV.) und ziemlich nahe die Anti-Apexstellung inne hat (Regel II), erscheint bei ihrer Mondbegegnung der Scheitel (4./5.); aber auch die Neptunwelle wahrt die Selbständigkeit, da

[2] Auch die solare Hemmung der von der Sonne aus gerechneten Venus-Marskonjunktion fiel auf diesen 28.

nach einer Herabminderung am 6. vor der Mondbegegnung (9.) am 7./8. hohe Werte erscheinen. Das Minimum 10.-13. ist das Ergebnis der Vorhemmung zum 20. An diesem Konjunktionstag selbst kämpfen positive und negative Faktoren um die Wette. Saturn sollte wegen der Sonnenopposition (26.) und der hinzutretenden Gegenspannung (23.) nach seiner Mondbegegnung (17.) einen Scheitel wecken. Schon bei der Annäherung an diesen 17. erscheinen, unterstützt durch Vollmond, am 15./16. höhere Zahlen. Dann sinken 17./18. wegen des unmittelbaren Merkur-Sonnenkonjunktions-Einflusses die Werte sehr tief, worauf mit elementarer Gewalt die zurückgedrängten Saturneinstrahlungen sich durchringen und die relativ hohen Zahlen 19.-21. verursachen, die hierauf durch 3 Dämpfungen am 23., 25. und 26. unterbrocken werden, aber nach der Saturn-Sonnenopposition (26.) wieder aufleben, um schliesslich nochmals am 30./31. Hemmungen zu weichen. Die zwiefache Mondbegegnung am 3. Juni muss wegen der darauffolgenden Planetenkonjunktion (9.), die noch nicht allzuviel von der Anti-Apexrichtung abweicht, etwas fördern; desgleichen noch Mond-Neptun am 5. Gleich auf diese Venus-Marskonjunktion vom 9. folgt dann die grösste dreitägige Summe im Juni (10.-12.). Aehnlich wie das Diagramm 1926 für Februar bezüglich der unteren Venus-Sonnenkonjunktion Wechselwirkung von Senkung und Anschwellung anzeigt, könnte auch diese planetare Konjunktion im ersten Momente vorläufig zurückhaltend gewirkt haben und so die niedrigen Zahlen 7.-9. veranlasst haben. Es war nämlich die gleichnamige solare Hemmung vom 28. April noch nahe genug. In Zusammenhalt mit der sicher Einfluss nehmenden, solaren Hemmung vom 24. Juni, gewinnt diese Vermutung an Wahrscheinlichkeit. Das durch letztgenannte Hemmung bewirkte, grosse Minimum vom 18.-25. Juni wurde schon unter (*B*) erörtert. Ihre Vorstörung schwächt bereits um den 14. die Zahlen, die wegen des Vollmondes (15.) noch kaum merklich zunehmen, um dann ins tiefe Minimum überzugehen. Die doppelte Mondkonjunktion zu Jupiter und Uranus am 22. muss nun bereits als Förderung gelten, weil die Sonnenkonjunktion über ein Vierteljahr absteht. Schon regt sich an diesem Termin kleine Schwankung. Aber die unmittelbare Einwirkung der solaren Hemmung hält noch den Einfluss zurück, der aber in den höheren Werten am 26./27. nachträglich zur Entfaltung gelangt, worauf am 29. Neumond wieder schwächt. Zu Beginn des 2. Halbjahres vereinigen sich schon im Juli zwei bedeutsame positive Einflüsse; die untere Merkur-Sonnenkonjunktion (20.) und die Vorwirkung der gemeinsamen Jupiter-Uranus-Sonnenopposition in den vorhergehenden Stillständen (9. und 25.). (Die Venus-Neptunbegegnung vom 2. dürfte kaum von Bedeutung sein, da Venus nahe 270°, also entfernt von Neptun steht.) Am 1. Juli wirkt daher Mond-Merkur positiv, am 2. Mond-Neptun negativ, worauf am 5. der Merkur-Stillstand eine höhere Zahlengruppe bis 9. hervorruft. Hernach hemmt die Saturn-Mondbegegnung vom 11. Diesmal folgt nämlich keine

fördernde planetare Gegenstellung wie im April und Mai. Während bereits damals diese Mondkonjunktion zunächst niedere Werte, wie auch im Juni, im Gefolge hatte, "(das Diagramm 1926 wies fast das ganze Jahr hindurch eine deutliche Hemmungs-Welle bei Saturn-Mond auf)", ist im Juli keine positive Zutat vorhanden; auch der früher gleich folgende Vollmond steht etwas weiter ab; daher die Ruhepause 9.-11. Nach kleiner Anschwellung beim Vollmond erscheinen 15./16. wieder niedere Werte wegen der Neptun-Marskonjunktion am 17., da beide Planeten schon ziemlich nahe der hemmenden Sonnenkonjunktion stehen. Sie hindert das sofortige Anschwellen der am 19. erregten Jupiter-Uranuswelle, die 21.-23. zum Scheitel führt. Nachher muss Merkur-Mond am 27. nochmals etwas fördern, aber sofort dämpft die Doppel-Mondbegegnung zu den hemmenden Planeten, während der Merkur-Stillstand und besonders die Mondbegegnung der Venus am 1. August, die schon nahe der unteren Konjunktion steht, fördern. Im August ist am 7. die Saturn-Mondhemmung wieder ersichtlich, an die sich die Vorhemmung vom 20. anschliesst, die am 13. zu völliger Ruhe führt. Wohl fördert an diesem 13. Vollmond, wohl schliesst sich am 15. die starke Wellenerregung an, die unmittelbare Konjunktionsnähe (20.) lässt, unterstützt durch Merkur-Perihel (19.), am 17./18. die Zahlen tief sinken; aber dann lässt sich die Zustrahlung nicht mehr aufhalten; es kommt zum Höchstwert (19-22.). Die konzentrierte Neptun-Merkurhemmung vom 27. und die darauf erscheinende Venuswelle wurden schon behandelt. Nach den Angaben der Tabelle kann der aufmerksame Leser selbst das Wechselspiel in den letzten 4 Monaten deuten. Erinnert sei nur, dass die Hemmungskonjunktion vom 16. September den Neptuneinfluss (23.) und die Neumondhemmung (25.) unterstützt, dass völlige Ruhe 22.-24. erzielt wird. Die dazu gehörigen Mondbegegnungen (26./27.) hindern eine nachträgliche Entfaltung der Venus-Welle (23.) zu einem eigentlichen Höchstwert.

Der Gefertigte glaubt, die hier besprochenen planetaren Faktoren auch quantitativ erfassen zu können, so dass aus dem astronomischen Kalender eine resultierende Kurve der planetaren Einflussnahme auf den Erdmagnetismus im vorhinein entworfen werden kann, die dann der Kurve der tatsächlichen Charakterzahlen zur Korrelation gegenübergestellt werden soll, sowie bezüglich der Sonnentätigkeit von der Tabelle für 1926 (Dez. heft 1928 S. 215) in einer Prognose 1929 in *Astr. Nachr.*, **234**, 405, und in einem Aufsatze in der *Met. Zs.*, 1929, S. 155, zu einem Diagramm fortgeschritten wurde.

Bemerkungen—st = Stillstände der Planeten: März 3., ☿; 18., ♄; 26., ☿; Mai 6., ♆; Juli 5., ☿; 9., ♅; 25., ♃; 30., ☿; Aug. 6., ♄; 18., ♀; Sept. 30., ♀; Okt. 30., ☿; Nov. 19., ☿; .20., ♃; Dez. 2., ♆; 10., ♅. (Ihre Bedeutung liegt nur in einer angenäherten Abgrenzung der planetaren Einwirkungsfrist, nicht so sehr in einer auf den Tag gehenden Einwirkung.)

P = Perihelien: Jan. 3., ♁; Febr. 24., ☿; Apr. 28., ♀; Mai 23., ☿; Aug. 19., ☿: Nov. 14., ☿; Dez. 9., ♀. Sie führen, wahrscheinlich wegen eingeleiteter elektrischer Ausgleiche, zu vorübergehenden Schwächungen der Schwankungszahlen.

Ein einzelnes planetares Zeichen bedeutet die von der Erde aus gesehenen Mondkonjunk-

ERDMAGNETISCHE CHARAKTERZAHLEN 1927

Tag	Jan.	Feb.	März	Apr.	Mai	Juni	Juli	Aug.	Sep.	Okt.	Nov.	Dez.
1	1.3	0.4	1.2 SK	0.5 ♅	0.4 *N*	0.9	☿ 1.0	♀ 0.7	1.2	0.3 ♄	(0.0)	0.8
2	0.7	0.2N ☿	0.3	0.5 *N*	0.5	1.0	*PK* 0.6 ♆	1.0	0.5 SK	0.9	*ZS*(0.0)	*st* 0.9
3	0.1 *N,P*	♀ 0.9 ♃	*st* 0.4N, ♃	0.3	1.3	♀, ♂ 0.6	0.1	0.9	0.6 ♄	0.8	(0.1)	♃, ♅ 0.2 S
4	♀ 1.5	0.4	☿ 0.2 ♅	♀ 1.0	♀ 1.0	0.3	0.2	0.8	1.4	0.1	0.5	0.0
5	1.0	PK, *ZS* 0.4 ♅	♀ 0.5	0.7	♂ 1.8	♆ 1.1	*st* 0.6	0.8	0.9	0.9	♃ (0.2)	0.9
6	0.8 ♃	0.0	0.6	*PK* 0.2	*st* 0.6	0.6	0.7	*st* 0.1	*PK* 1.2	1.0	♅ (0.1)	1.0
7	1.0	*PO* 0.0	0.5	♂ 0.9	1.6	0.3	1.0	0.2 ♄	1.2	1.5	(0.0)	0.7
8	1.1 ♅	0.8	0.7	0.9	1.0	0.0	0.9	0.3	1.2	1.3	0.6	*V* 0.7
9	0.1	♂ 1.5	*PO* ♂ 1.4	1.4	♆ 0.9	*PK* 0.1	*st*(0.1)	0.2	1.4	♃, ♅ 1.0	*V* 0.4	*PK* 0.7 P
10	0.1	1.2	1.3	0.8	(0.3)	0.7	(0.0)	0.2	SK 1.6	*V* 1.8	SK 0.2	*st* 0.6
11	0.8	0.5	0.8	♆ 1.5	(0.0)	1.0	(0.2) ♄	0.3	*V* 1.0	0.0	0.2	0.1
12	♂ 0.8	1.0	0.5	1.0	(0.0)	1.0	0.2	0.2	♃, ♅ 0.5	2.0	0.2	0.3
13	0.5	*PK* 1.1 ZS	SK 0.8	0.9	(0.3)	0.3 ♄	0.3	*V* 0.0	0.9	1.7	*PK* 0.5	♆ 1.7
14	0.7	0.6	0.8	1.0	0.5	0.5	*V* 0.2	0.4	1.0	0.7	0.0 *P*	1.4
15	*ZS* 0.3	SO 0.4	♆ 1.1	0.9	1.2	*V* 0.6	0.1	0.8	0.8	0.4	0.0	1.2
16	0.2	*V*, ♆ 1.1	1.8	(0.1)	*V* 0.9	0.2	0.1	♅, ♃ 0.7	0.2 *PK*	0.3	0.4	0.7
17	*V* 0.6	0.7	1.6	*V*(0.0) PK	♄ 0.1	0.6	0.9 *PK*	0.2	0.2	0.1	0.2 ZS	*PK* 1.3
18	0.6	0.9	*st*, *V* 1.1	(0.1)	0.1	(0.1)	0.2	*st* 0.2	0.2	0.3	1.5	1.2
19	0.8	0.7	0.9	(0.1)	1.0	(0.0)	♅, ♃ 0.7	0.9 P	0.2	0.5	*st*, ♀ 0.8	1.1
20	♆ (0.1)	0.4	PK 1.0	♄ (0.1)	1.4 SK	(0.0)	SK 0.7	0.2 SK	0.7	0.5 ♆	*st* 0.7	♀ (0.0)
21	(0.0)	(0.1)	(0.2) SK	(0.0)	0.6	(0.1)	1.6	2.0	0.4	♀ 0.1 SK	0.8	(0.0)
22	*ZS*(0.0)	(0.0)	(0.1)	(0.0)	0.4	♃, ♅ 0.3	2.0	0.8	SO(0.1)	2.0	☿ 0.1	(0.1) ♂,
23	(0.1)	(0.0)	(0.1)	*PO* 0.9	*PO* 0.3 *P*	(0.2)	1.1	0.5	♀ (0.0) ♆	1.9	0.0 ♂	☿ 0.5
24	1.1	*PK* 1.4 P	♄ (0.0)	1.2	0.2	(0.0) ZS	0.8	(0.2)	(0.1)	1.0	0.4 *N*	0.1 *N*
25	1.1	♄ 1.1	(0.1)	0.9	0.3 ♃	(0.1)	*st* 0.4	(0.0)	SO 1.0 *N*	0.8 *N* ♂	0.0 ♄	0.1
26	1.1	1.0	*st* 1.3	(0.2)	SO 0.1 ♅	1.3	0.7	(0.0) ☿, ♆	1.0 ♂	0.9	0.3	0.3 *P*
27	0.3	0.6	1.7	(0.1)	1.0	0.7	☿ 0.8	*PK* 0.3 PK, *N*	0.8 ☿	☿ 0.3	0.5	0.1
28	0.2 SK	1.1	1.6	(0.0) ♃, ♅, P	1.2	0.3	0.2 *N*	♀ 0.2 ♂	0.7	0.3 ♄	0.1	1.3
29	0.6	...	0.9	0.3	0.4	0.3 *N*	0.1	1.5	1.0	0.7	0.8	0.5
30	*PO* 0.3	...	0.8	0.5 ☿	0.2 *N*	0.7	*st* 0.3 ♆, ♂	1.5	*st* 0.9	*st* 0.8	0.9	♃, ♅ 0.1
31	0.1	...	☿ 0.6 ♃	...	0.2 ☿	...	0.3	0.9	.....	(0.1)	...	0.8
M	0.62	0.66	0.80	0.60	0.65	0.47	0.56	0.61	0.77	0.84	0.35	0.63

tionen zu den betreffenden Planeten, z.B. 4. Jan., ♀☌☾; 6. Jan., ♃☌☾. Sie haben keinen selbständigen Einfluss, sondern spitzen einen jeweils vorhandenen positiven oder negativen Einfluss des betreffenden Planeten ziemlich rasch zu. Im ersten Falle steht die Angabe links von den Zahlen, wie für 4. Januar, im zweiten rechts, wie für 6. Jan. Weil im Jahre 1927 die betreffs der Erregung der Sonnenflecken sehr wichtige Jupiter-Uranuskonjunktion einfiel, sind die gemeinsamen Mondbegegnungen von Jupiter und Uranus stets eingetragen und zwar in den ersten 5 Monaten wegen der Nähe der hemmenden Sonnenkonjunktionen rechts in der Spalte der Hemmungen, dann später wegen der fördernden Doppel-Sonnenopposition unter den positiven Faktoren. Aehnlich ist die Merkur-Mondbegegnung in der Nähe der unteren Merkur-Sonnenkonjunktion als Förderung auslösend, in der Nähe einer oberen als Hemmung betonend angesetzt. Bei Uebergängen ist ein Einfluss fraglich, weshalb der Mondkonjunktions-Termin nicht eingetragen ist. Aus dem gleichen Grunde entfallen für je einen Monat die Angaben für Neptun, Saturn, Mars und Venus.

V = Vollmond; *N* = Neumond; erstgenannter betont in untergeordneter Weise die jeweils vorhandene Förderung, letztgenannter eine etwaige Schwächung.

SK = Solare Konjunktionen: Der angegebene Planet kommt, von der Erde aus gesehen, zur Sonne in Konjunktion. Diese bilden die *hauptsächlichsten Hemmungsfaktoren mit Ausnahme der unteren Sonnenbegegnungen* der inneren Planeten, welche umgekehrt positiv fördern (*u* bezeichnet eine untere, *o* eine obere Sonnenkonjunktion). Jan. 28., ☿ *V*; März 1., ♃; 13., ☿ *u*; 21., ♅; Mai 20., ☿ *V;* Juli 20., ☿ *u;* Aug. 20., ♆; Sept. 2., ☿ *o*; 10., ♀ *u;* Okt. 21., ♂; Nov. 10., ☿ *u;* Dez. 3., ♄.

S.O. = Solare Oppositionen: Die angegebenen Planeten kommen, von der Erde aus gesehen, zur Sonne in Opposition. Sie stellen die *hauptsächlichsten Förderungen* dar. Febr. 15., ♆; Mai 26., ♄; Sept. 22., ♃; 25., ♅.

PK = Planetare Konjunktionen: Die beiden Planeten kommen von der Erde aus zueinander in Konjunktion. Sie erzielen stets Vergrösserungen der magnetischen Schwankungszahlen, falls wenigstens einer solar fördert, bei beiderseitiger Förderung sogar in bedeutendem Maasse; hingegen schwächen sie intensiv, wenn beide solar hemmen. . . Febr. 5., ♀☌♃; 13., ☿☌♃; 24. ♀☌♅; März 20., ☿☌♃; Apr. 6., ☿☌♃; 17., ☿☌♅; Juni 9., ♀☌♂; Juli 2., ♀☌♆; 17., ♂☌♆; Aug. 27., ♀☌♂; ☿☌♆; Sept. 6., ☿☌♀; 16., ☿☌♂; Dez. 9., ☿☌♂; 17., ☿☌♄; 26., ♂☌♄. Die bisher angeführten Konstellationen finden sich meist in den astronomischen Jahrbüchern angegeben.

PO = Planetare Oppositionen: Von der Erde aus kommen die beiden Planeten zueinander in Opposition. Die Stellung wird aus dem Rektaszensions-Unterschied von 180° ermittelt. Sie erzielt schwache Förderung, die bei der benachbarten Mond-Konjunktion eines der beiden Planeten zu Tage tritt. . . Jan. 30., ♀☍♆; Febr. 7., ☿☍♆; März 9., ♂☍♄; Apr. 23., ♀☍♄; Mai 23., ☿☍♄.

ZS = Zentral-Solare Stellungen: Es gelangen von der Sonne aus zwei von der Erde verschiedene Planeten in Konjunktion oder Opposition, was aus der Uebereinstimmung ihrer heliozentrischen Längen, bzw. aus deren Unterschied von 180° ersehen wird. Im Dezemberheft 1928 S. 215 finden sie sich als Einstrahlungsursachen Auslösungs- und Hemmungs-Faktoren bezüglich der Sonnentätigkeit angeführt. Sie erzielen keine unmittelbare Einwirkung auf die Erde, jedoch unter Umständen, die im Texte erwähnt sind, eine indirekte (durch Aenderung der Sonnenstrahlung). Darunter sind jene, die nur gelegentlich wegen gewisser Begleiterscheinungen (also nicht bei ihrem jedesmaligen Eintreffen) registriert sind, in Klammern gebracht: (Jan. 15., ♀☍♆; 22., ♀☌♃;) Febr. (5., ☿☌♃; ♀☌♅;) 13., ☿☌♀; Juni 24., ☿☌♀; Nov. (2., ☿☌♃;) 17., ☿☌♀.

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REVIEWS AND ABSTRACTS

(See also page 264)

Whipple, F. J. W.: *On the association of the diurnal variation of electric potential-gradient in fine weather with the distribution of thunderstorms over the globe.* London, Q. J. R. Met. Soc., v. 55, No. 229, Jan., 1929 (1-17).

In the polar regions and over the oceans, the diurnal-variation curve for the potential gradient is of a simple type, especially in the winter, with but one maximum and one minimum. The time of occurrence of these was shown first by Mauchly to be simultaneous over the globe. According to Wilson's thunderstorm theory, the total charge flowing to the Earth will vary with the number and intensity of thunderstorms which, in order to account for the diurnal-variation of the potential gradient, would be a maximum and minimum when the potential gradient is a maximum and minimum, respectively.

The frequency and distribution of thunderstorms were given in 1925 by Brooks in three maps, one for northern summer, one for southern summer, and

one for the year. By using these and taking areas also into consideration, the author obtained a measure of the "effectiveness of thunderstorms." It is well known that over land thunderstorms are most frequent during the afternoon, but in view of the uncertainty of present data regarding the character of the diurnal variation of thunderstorms over the oceans, the author has regarded the storms there as equally likely to occur at any hour by Greenwich time. The two curves obtained, one for the northern summer and the other for the southern summer, showing the variation in "effectiveness of thunderstorms" during a Greenwich day, resemble the diurnal-variation curve of the potential gradient in polar regions and over the oceans. The author considers it important that the times of maximum and minimum for thunderstorms and for the potential gradient approximately coincide and that there are striking similarities in certain incidental features.

The reviewer first wishes to point out that Mauchly at no time found evidence for saying that anything other than the 24-hour wave of the potential gradient progresses according to universal time. In fact, he constantly cautioned against judging a curve from external appearances alone without subjecting it to a Fourier analysis. A number of investigators appear to disagree with Mauchly in this respect. Some have been very slow to accept the evidence of any variation in the potential gradient, especially over land, that progresses according to universal time, basing their argument principally upon external appearances alone.

In view of what has been said above, the author's storm-curves as well as the potential-gradient curves for the polar regions have been subjected to Fourier analysis. The following table shows the times of maximum and the amplitude of the 24-hour wave derived from these analyses. Mauchly has emphasized the

Element	Place	Time and amplitude of maximum			
		Northern summer		Southern summer	
		G.M.T.	Amplitude	G.M.T.	Amplitude
		h	% of mean	*h*	% of mean
Poetential gradient	Karasjok	17.7	19	16.1	34
" "	Cape Evans	19.2	12	15.0	23
" "	All oceans	19.1	10	16.4	14
Thunderstorms	Globe	15.7	12	16.2	22

fact that there is an annual variation in amplitude and phase-angle of the 24-hour wave over the oceans, as derived from the *Carnegie* results. The amplitude being smaller and the time of the maximum being later in the Greenwich day for the northern summer than for the southern summer. As will be seen from the table, the analyses for the potential gradient give a similar thing in the present case. A similar change in amplitude is observed for the thunderstorm analysis but the shift in time of the maximum is very small and in the opposite direction.

It is true as pointed out by the author, that enough data regarding the times of occurrence of thunderstorms and their distribution have not yet been collected to permit a very exact test of Wilson's theory by this method. In addition, it would be very desirable to have tests on the fields beneath clouds, both with respect to sign and intensity, and to carry these tests over as large a portion of the globe as possible. The author has done well with the existing data, and should continue this line of attack as more data accumulate. G. R. WAIT

DIE ENERGIEMASSE UND DER ELEKTRIZITAETSHAUSHALT DER ERDE

Von G. Maneff

Uebersicht—Es wird versucht, mit Hilfe der Inversion des Gravitations- und Elektromagnetischen Feldes, den Elektrizitätshaushalt der Erde und die Frage nach der Natur des Gegenstromes, wie auch die physikalische Ursache des Erdmagnetismus klarzulegen.

Es ist bekannt, dass gegen alle Hypothesen, die den Elektrizitätshaushalt der Erde und die Energiequelle des Gegenstromes, wie auch die physikalische Ursache des Erdmagnetismus zu erklären versuchen, schwerwiegende Einwände zu erheben sind.

Ich werde nun versuchen diese Frage zu erläutern mit Hilfe der von mir bei der Rotationsbewegungen behandelten Inversion des Gravitations- und des elektromagnetischen Feldes die als Ergebnis des erweiterten Prinzips der Wirkung und Gegenwirkung hervortritt.[1]

§1. Bestimmen wir also nach der erwähnten Inversion der Felder auf rein mechanischem Wege die Zentrifugalkraft der trägen und schweren Massen der Energie, so wird damit auch der absolute Wert der ponderomotorischen Kraft des elektromagnetischen Feldes gegeben, d. h.

$$[F]=m_e v^2/r \text{ .... } (1)$$

wo

$$M_e=3\kappa Mm/c^2 r=3mv^2/c^2 \text{ .... } (1)'$$

d. h. die eigene Energiemasse des bewegten Körpers und diese, welche infolge der Wirkung des selbstständigen Feldes entsteht.

Aus (1) erhält man den Druck auf die Flächeneinheit und aus dem bekannten Ausdruck der Elektrodynamik

$$P=2\pi h^2 \text{ .... } (2)$$

die Flächenladung. Mit Hilfe dieser beiden Ausdrücke können wir die Rotationsbewegung der Erde um die Sonne untersuchen.

Setzten wir in (1) für M den Betrag der Sonnenmasse, für κ die Gravitationskonstante, für m die Masse eines c.cm von der mittleren Erddichte$=5.5$, für v die mittlere Erdgeschwindigkeit, für r den mittleren Abstand Sonne-Erde, und $c=3\times10^{10}$cm/sec., so werden wir noch mit Hilfe von (2)

$$h=1.24\times10^{-4}\text{ e.s.e .... } (3)$$

erhalten, und für die Flächenladung der ganzen Erde

$$H=6.4\times10^{14}\text{e.s.e .... } (4)$$

Die Erde dreht sich aber auch um ihre Achse. Führen wir für diese Drehung dieselbe Rechnung aus, so erhalten wir

[1] *Annu. Univ. Sofia, Faculté phys. math.*, 2, 1, 1928-1929.

$$h' = 0.79 \times 10^{-4}\,\text{e.s.e} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

und

$$H' = 4.06 \times 10^{14}\,\text{e.s.e} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Will man die gesamte theoretische Oberflächenladung der Erde aus (4) und (6) auffinden, so erhält man die Zahl

$$10.46 \times 10^{14}\,\text{e.s.e} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

wogegen aus luftelektrischen Messungen sie zu

$$10 \times 10^{14}\,\text{e.s.e. (Kähler) und } 13.5 \times 10^{14}\,\text{e.s.e (Schweidler)} \ldots \quad (8)$$

bestimmt worden ist, also Zahlen von der gleichen Grössenordnung.

Wenn wir die Erde als einen gesonderten absoluten Leiter betrachten und (1) auf die Masse der Energie der ganzen Erde beziehen, so erhalten wir mit Hilfe der bereits angewandten Methode, indem wir nähmlich die so gewonnene Ladung nur auf die Oberfläche verteilen, für die durch die Bewegung um die Sonne hervorgerufene Gesamtladung

$$H'' = 7.4 \times 10^{18}\,\text{e.s.e} \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Bei der Rotation der Erde um ihre eigene Achse haben wir zu beachten, dass der Druck bzw. die Ladung eine Funktion des Radius ist, so dass man einen geringeren Wert im Verhältnis zu (9) erhält.

Da aber hier der Gravitationseinfluss eines materiellen Centrums auf die Energiemasse behandelt wird, so gibt es in elektromagnetischem Sinne auch eine Einwirkung einer positiven Ladung auf eine negative. Wie in der vorangehenden Arbeit betont wurde, ändert sich der skalare Charakter der Ladung bei der Inversion nicht; dies macht es begreiflich, weshalb die elektrische Erdladung negativ ist.

§2. Man kann infolge der sehr geringen Leitfähigkeit der Erdatmosphäre mit Raumladungen rechnen. Führt man (1) und (2) auf Gase von verschiedener Dichte d zurück, so erhält man

$$h_1 : h_2 = \sqrt{d_1} : \sqrt{d_2} \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Dieser Ausdruck zeigt uns, dass mit Abnehmen der Atmosphärendichte auch die Oberflächenladung bzw. die Raumladung abnimmt. So dass schliesslich das elektrostatische Potential mit der Atmosphärenhöhe abnimmt und an die Atmosphärengrenze verschwindet; die Abnahme selbst ergibt als Resultat vertikale Ströme. Die Atmosphäre erscheint als der Sitz eines elektrischen Feldes mit der Erdoberfläche als Kathode, deren Kraftlinien in freiem Aether enden.

Das Erdinnere kann auch als ein elektrisches Feld betrachtet werden, welches aber grössere absolute Potentiale erhält. Bei der Erdbewegung um die Sonne könnte man einfach so rechnen, als ob alle Erdpunkte die gleichen elektrischen Potentiale erhalten

da der Erdradius sehr klein im Verhältnis zum Abstande Sonne-Erde ist. Dasselbe kann bei der Drehung der Erde um ihre Achse nicht gemacht werden: die von dieser Drehung verursachte Ladung an der Erdoberfläche selbst ist, wie wir sahen, ungefähr von derselben Grössenordnung, wie die von der Bewegung um die Sonne verursachte. Diese Ladung wird aber mit abnehmendem Erdradius stetig abnehmen, um an der Erdachse selbst zu verschwinden. So werden also vertikale, den atmosphärischen entgegengerichtete Ströme auftreten müssen.

Es ist selbstverständlich, dass es für einen ununterbrochenen Nachschub der Vertikalströme sowohl in dem Erdinneren, wie auch in der Atmosphäre gesorgt sein muss. Darin besteht die wichtige Frage des Gegenstromes. Da die Bewegungen der Erde unaufhörlich fortdauern, so werden nach der hier entwickelten Theorie auch die Zentrifugalspannungen des elektromagnetischen Feldes ununterbrochen bestehen bleiben.

Die Erde spielt bei der Erscheinungen der atmosphärischen Elektrizität die Rolle einer isolierten Kathode, die durch den Leitungsstrom beständig entladen wird — wie bei der Glimmentladung — und den auf den Aether ausgeübten Druck der Energiemasse wieder unaufhörlich aufgeladen wird. Es handelt sich hierbei um ein dynamisch-stationäres Gleichgewicht, und nicht um ein vorübergehendes Phänomen. Selbstverständlich muss das Energieprinzip völlig erfüllt bleiben; das Zustandekommen eines fast konstant bleibenden elektromagnetischen Feldes im Erdinneren und in der Erdatmosphäre geschieht auf Kosten der Erdenergie.

§3. Alles obendargelegte bezieht sich auf eine statische Verteilung der Spannungen, bzw. des elektrostatischen Potentials. Infolge der Erdumdrehung bilden aber diese Spannungen im Ruheäther relativ gegen die Erde scheinbare Verschiebungsströme, die die Breiten entlang, entgegen der Rotationsrichtung der Erde, fliessen werden. Diese elektrischen Ströme liefern den Erdmagnetismus.

Bekanntlich sind die rein elektrischen Theorien zur Erklärung des Erdmagnetismus die wahrscheinlichsten. Aber auch diese haben ihre wesentliche Mängel: (*a*) alle innere Erdströme hätten gleiche Richtung mit der Erdrotation, (*b*) bis jetzt ist es unmöglich gewesen eine Quelle der dazu nötigen elektromotorischen Kräfte aufzufinden.

In der hier entwickelten Theorie sind beide Defekte völlig beseitigt. Die obenerwähnten Verschiebungsströme im Aether, die sich von der Reaktion der Energiemasse und der Erdrotation ergeben, haben entgegengesetzte Richtung der Erdrotation, und dies liefert die genau beobachteten Magnetpolen der Erd. Die beständige Translations- und Rotationsbewegung der Erde erklärt uns die stetige und ununterbrochene Bewahrung der elektromotorischen Kraft.

§4. Es bleibt die Frage noch unentschieden, ob diese Verschie-

bungsströme die Hauptursache des beobachteten Erdmagnetismus bilden.

Indem Bauer[2] von Messungen der horizontalen Feldintensität ausgeht, errechnet er mit Hilfe des Ausdruckes für die Stromstärke

$$4\pi I = \int H ds \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

für diese Grösse Werte, die rund 10^4 mal grösser sind als die durch luftelektrische Messungen erhaltenen. Dabei haben diese vertikalen Ströme gerade umgekehrte Richtung der luftelektrischen.[3]

Vergleichen wir (9) mit dem entsprechenden aus luftelektrischen Messungen erhaltenen Wert (8), so bekommen wir etwa dieselbe obige Zahl 10^4. Und da in (11) I für uns die gegebene und H die zu ermittelnde Grösse ist, so entspricht das theoretisch berechnete H der experimentell gefundenen Zahl.

Ausserdem stimmt auch die Richtung unserer vertikalen inneren Erdströme mit den Bauerschen Vertikalströmen völlig überein, denn wie oben erwähnt, haben sie die entgegengesetzte Richtung der atmosphärischen Ströme.

Schliesslich spielen die schwachen Verschiebungsströme in der Erdatmosphäre, wie auch jede andere äussere Ursache ausserhalb der Erde, eine ganz untergeordnete Rolle. Massgebend bleiben nur die durch den Zentrifugaldruck der Energiemasse der Erde hervorgerufenen Aetherspannungen, welche infolge der Rotation ihrerseits die Verschiebungsströme verursachen. Dies alles ist in voller Uebereinstimmung mit den von Bauer[4] auf Grund eines zahlreichen experimentellen Materials erhaltenen Ergebnis, wonach die an der Erdoberfläche wahrnehmbaren Magnetkräfte zu 94 Prozent auf magnetische und elektrische Ursachen zurückzuführen sind, die ihren Sitz im Erdinnern haben.

§5. Man kann auch ohne tiefer in die Erscheinungen des Erdmagnetismus und der Erdelektrizität einzudringen, noch einige Erfahrungstatsachen erwähnen, die zu unseren Gunsten sprechen. So findet Bauer,[5] dass die täglichen und jährlichen Schwankungen des Potentialgefälles der atmosphärischen Elektrizität neben bestimmten lokalen Eigenschaften ausgesprochene Züge von weltweitem Charakter haben, d. h. sie finden in nämlichem Augenblicke über die ganze Erde hin statt, wie es bei den grossen Störungen des Erdmagnetismus der Fall ist. Dies verbindet er übrigens mit der Sonnenaktivität. Es genügt nur unsere (1) und (2) auf das Aphelium und Perihelium der Erde anzuwenden, um aus dem entsprechenden Ausdrucke für $v/r=w$ für diese beiden Orte einen Spannungsdifferenz F von 12 Prozent und für h ca. 3. 5 Prozent zu finden. Die Richtung dieser Aenderung

[2] *Terr. Mag.*, v. 25, 1920 (145-162).

[3] *Phys. Rev.*, v. 17, 1921 (424-426).

[4] *Phys. Rev.*, v. 21, 1923 (370-371).

[5] *Phys. Rev.*, v. 23, 1924 (303).

stimmt mit den beobachteten Schwankungen des Potentialgefälles sowohl in der nördlichen, wie auch in der südlichen Erdhälfte überein.

Eine andere Tatsache, die als eine vollkommene Stütze unserer Theorie gelten kann, und die wir nur kurz erwähnen, ist die Existenz innerer horizontalen Erdströme und deren Richtung.

Bekanntlich genügt der Lichtdruck zur Erklärung der Sonnenkorona und der Kometenschweife nicht. Man ist hingegen gezwungen noch elektrische und magnetische Kräfte zu hilfe zu ziehen. Der Ursprung dieser elektrischen Felder ist nach unserer Anschauung bekannt. Beispielsweise ist die Oberflächenladung der Sonne nur durch die Drehung der Sonne um ihre Achse hervorgerufen und, ermittelt auf ähnliche Weise wie bei der Erde, gleich

$$h'' = 3.7 \times 10^{-4} \text{e.s.e.} \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Berücksichtigen wir, dass diese Zahl höher als die entsprechende für die Erdladung herauskommt, und dass die lineare Geschwindigkeit der Sonnenoberflächenpunkte viel grösser als die entsprechende der Erdoberfläche ist, so ergibt sich, warum die beobachteten elektrischen und magnetischen Felder der Sonne viel stärker sein müssen.

Schliesslich, erfahren die Kometen bei ihrer Annäherung an die Sonne nicht nur einen grösseren Lichtdruck, sondern auch $w = v/r$, bzw. die Intensität der elektrischen Felder nimmt zu; es werden also die günstigen Bedingungen für eine Schweifausbreitung vermehrt.

SOFIA, PHYSIKALISCHES INSTITUT DER UNIVERSITÄT,
2. Mai 1929

NOTES

(See also pages 240 and 248)

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18. *British East African Meteorological Service*—There was inaugurated on January 1, 1929, a joint meteorological service with central offices at Kabete in Nairobi (Kenya Colony), which will embrace the area between the Egyptian and Sudan Service on the north and Rhodesian and South African Service on the south and link up with the South Indian Ocean Service on the east. The organization of the new Service has been entrusted to A. Walter, formerly Director of the Royal Alfred Observatory, Mauritius. One first-order station has already been erected and it is expected that four other first-order stations and about forty second-order stations distributed over the Lake Basin Area, will be equipped during the next few years. At the five first-order stations it is proposed to secure, in addition to the usual observations of pressure, wind-direction, wind-velocity, temperature, rainfall, and cloud, determinations of solar radiation, magnetic elements, and electrical potential of the atmosphere, as well as observations of the upper currents by means of pilot-balloon ascents. The inauguration of this Service fills a considerable gap in the chain of the World's meteorological services

and will make possible detailed observations over a zone which, from the viewpoint of the general circulation of the atmosphere, is a very important one. The new Service will issue the following publications: (1) A monthly bulletin of all observations secured; (2) a series of annals in which records, as far back as can be obtained, will be collected and published; and (3) a series of memoirs dealing with special investigations. The first of these memoirs, from which the greater part of the information given in this note is taken, bears the title "Note on the inauguration of a Joint Meteorological Service for British East African Territories."

19. *New Antarctic Expedition*—In August, 1929, a British expedition under the leadership of the well-known explorer Sir Douglas Mawson, will leave England for the antarctic regions. It is planned first to explore the south polar zone to the south of the Atlantic and Indian Oceans between longitudes 0° and 90° east, in other words, the Enderby Quadrant, comparatively little of which has been visited, and later to extend the investigations which Mawson so successfully carried out in 1912 and 1913 on the antarctic continent. The expedition will make use of the *Discovery* (the vessel which carried Scott's expedition to Antarctica in 1901-1904) under the command of Captain J. K. Davis, who was associated with Mawson in a similar capacity on the Australasian Antarctic Expedition of 1911-1914. The vessel will carry an aeroplane with floats for alighting on and rising from the sea, and a ski-carriage for use on ice and snow. Long-wave and short-wave wireless equipments will also be carried. The crew will consist of 28 officers and men exclusive of the 12 scientists who will participate in the Expedition. The enterprise is being sponsored by the governments of Australia, New Zealand, and Great Britain. Several private contributions have also been made to the funds of the Expedition.

20. *International Geodetic and Geophysical Union*—The fourth general assembly of the International Geodetic and Geophysical Union will be held at Stockholm, Sweden, August 17 to 25, 1930. The Parliament Building (Riksdagshuset) in which all except the opening meeting will be held will be available for the use of any of the sections which may desire to begin work before the formal opening of the meetings. During and after the meetings excursions have been arranged by the Swedish Committee with a view to acquainting the visitors with the industries, natural resources, and scenic beauty of the country.

It is desired that any member of the Section of Terrestrial Magnetism and Electricity who intends to present a communication at the meetings should send the title before January 1, 1930, to Prof. Ch. Maurain, Secrétaire de la Section et Directeur du Bureau Central, 191, rue Saint-Jacques, Paris V^{e}, in order that it may be duly printed in a circular of preliminary information which will be sent to all members of the Section. Professor Maurain in sending out the preliminary program to the secretaries of the sections of Terrestrial Magnetism and Electricity requested them to send him corrected lists of the members of their sections and suggestions for the agenda of the Stockholm meeting, together with a report of work done in terrestrial magnetism and electricity in their respective countries since the last meeting of the Union at Prague in 1927.

A LEAK-FREE METHOD OF MEASURING AIR-POTENTIALS

By O. H. Gish and K. L. Sherman

The advantage of null methods of measurement is generally appreciated by physicists. Another device of great service in certain classes of electric measurements is the guard-ring. These two devices were embodied in an arrangement designed by the senior author for the purpose of eliminating errors which are likely to arise in certain types of atmospheric-electric measurements from inadequate insulation. These errors are difficult to detect unless they amount to 20 per cent or perhaps considerably more. Their effect may falsify not only the measure of the absolute values but also that of the variations.[1] Furthermore under certain unfavorable conditions the insulation may become so incurably defective that measurements by the usual methods must be temporarily abandoned. With the arrangement which is described in the following paragraphs, measurements free from these uncertainties are obtained.

When first arranging to make use of this design the junior author suggested important modifications which were found especially advantageous with the equipment that was immediately available. He also made all the observations. These were measurements of air-potential in which a Wulf-type bifilar electrometer was used and it is this specific arrangement that will be described.

Description of method—A schematic diagram of the arrangement is shown in Fig. 1. The fibers of the electrometer are connected with the collector A. An auxiliary potential sufficient to deflect the fibers to the more sensitive part of their range when they are at earth potential is maintained between the inner and outer case. The entire electrometer and the auxiliary-potential batteries rest on insulating supports. A guard-ring, B, which completely surrounds the prime insulator of the collector-system, is connected with the outer case of the electrometer, which in turn is connected with the sliding contact, E, of the slide-wire rheostat C. A battery whose e. m. f. is as large as the highest potential to be measured is connected across the ends of the slide-wire and one end of this connects to earth. The potential on the outer case of the electrometer is measured by a voltmeter, D, of suitable range, which is connected between the outer case and the earthed terminal of the slide-wire.

Suppose that at the outset the collector system together with the fibers and the sliding contact, E, are all earthed and that, with the auxiliary potential applied to the inner case, the fibers are deflected d scale-divisions. Then as the potential of the collector-system increases the deflection of the fibers will increase by an amount approximately proportional to the change of the potential between the fibers and the inner case. If now the contactor E is moved

[1] Benndorf, H., Handbuch der Experimentalphysik, Bd. XXV, 1. Teil, pp. 317-319.

until the fiber-deflection is restored to the value d then the difference of potential between fibers and inner case is the same as at the outset, consequently the potential of the inner case and obviously

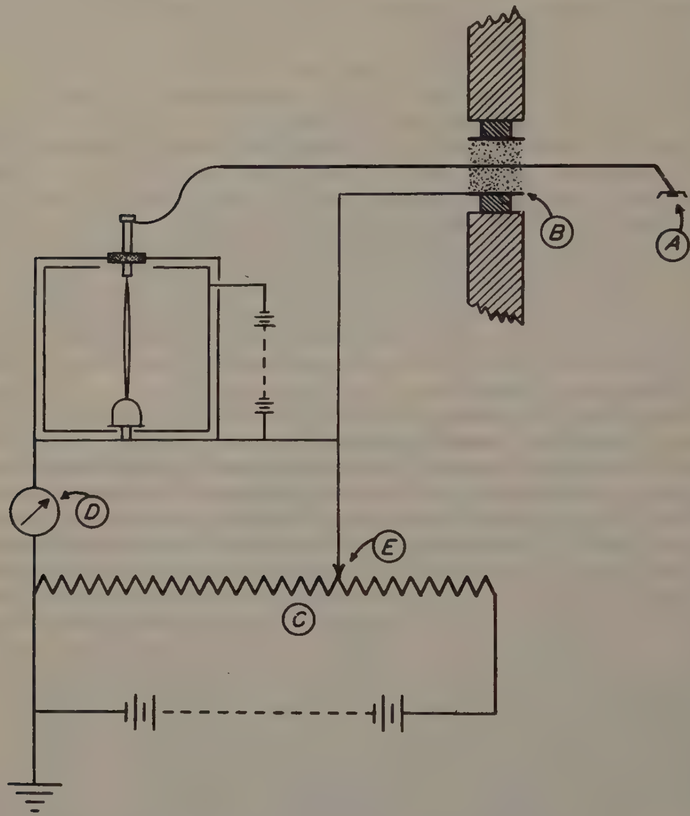

Fig. 1—No-leak method for measuring air-potentials

also that of the outer case and guard-ring have increased by an amount equal to the potential acquired by the fibers so that the outer case and guard-ring are now at the same potential as the collector-system and fibers. With this condition established throughout a measurement no transport of charge takes place across either the insulators of the electrometer or that supporting the collector-system. Furthermore the potential of the outer case and hence that of the collector-system is now indicated directly by the voltmeter, D.

In order to determine whether the "zero" deflection d has changed it is only necessary to momentarily connect the fibers with the outer case. This does not entail delay since the fibers are not thereby earthed as would occur in making this test with the usual

method. Another advantage which should be noted is that this method is practically self calibrating. The slide-wire rheostat is the only part required in addition to the equipment regularly used in the usual method.

Comparison of results obtained simultaneously with new and old method—Observations for comparing the new with the old method were made on two Simpson stretched-wire systems mounted about 18 inches apart on the roof of the laboratory. Each system consisted of a radioactive collector mounted on a wire about 30 feet long stretched tightly between sulfur-insulators. The activity of each of the collectors used in the tests was about twice that of the Department of Terrestrial Magnetism laboratory standard which has a charging factor (or effective conductance) of about 2.5 E.S.U.

The order of observation was to first so adjust the potential-divider of the null method that the fibers would take their "zero" deflection. Immediately after this adjustment the fiber-positions of the other electrometer were read and recorded. Next, the voltmeter of the new method was read and the value recorded. Twenty such pairs of simultaneous readings taken at one-minute intervals comprise a set. The apparatus was so arranged that each stretched-wire could be easily connected for measurements by either method. The usual procedure was to alternate methods by sets. During the observations reported in Table 1, relatively large artificial leaks were introduced on one collector-system while on the other, system (1), sulfur strain-insulators of unknown age were used without cleaning or other treatment. This procedure was designed to test the reliability of the new method under conditions which would seriously falsify results obtained with the old method.

Referring to Table 1 which is largely self-explanatory, the observations reduced to volts are entered in the third and fifth columns and the ratio of the potentials measured on system (1) to those obtained for system (2) occurs in the last column. Sets 1 and 4, obtained without artificial leaks, determine the normal ratio between the potentials of system (1) and those of system (2). The fact that although the methods are interchanged in these two sets yet no appreciable change in the ratios occurs, shows that the normal insulation-leak is negligible. Sets 2 and 5 show that when using the old method on system (2), with the artificial leaks, the ratio was increased 15 per cent whereas with the new method in use on this system, as in sets 3 and 6, the ratio did not differ appreciably from the normal value. As will be seen in sets 7 and 8, leaks which give rise to errors of 40 per cent when using the old method are innocuous when using the new method.

Since it was necessary to dismantle and reassemble at least one of the stretched wires between the various dates, the leak-free ratio of the stations cannot be expected to remain constant from day to day. However, no changes that would alter this ratio were made during the observations of a single day.

TABLE 1—*Observations for comparing new method with old using artificial leaks, May 31, 1929*

Set No.	Artificial leak	System (1)		System (2)		Ratio (1)/(2)
		Reading	Method	Reading	Method	
		volts		*volts*		
1	None	101.9	New	97.2	Old	1.05
2	On system (2)	106.8	New	92.8	Old	1.15
3	On system (2)	105.2	Old	99.1	New	1.06
4	None	99.1	Old	95.4	New	1.04
5	On system (2)	93.2	New	79.0	Old	1.18
6	On system (2)	123.1	Old	118.4	New	1.04
Leak increased						
7	On system (2)	92.2	New	63.0	Old	1.46
8	On system (2)	107.4	Old	102.0	New	1.05

In another series, observations were made for the purpose of determining the adequacy of the sulfur strain-insulators of the type used in the Department of Terrestrial Magnetism with the stretched-wire method of measuring potential gradient. The insulators were given no special care, but laboratory measurements made prior to the observations indicated for the combined insulation a resistance of about 10^{15} ohms. Weather conditions were favorable, probably such as, on the average, exist on days selected for making reduction-factor observations.

The results of these tests are shown in Table 2. The mean ratio from the five sets obtained when using the new method on system (1) and the old on system (2) is 1.072, whereas the mean of four sets obtained when the new method was used on system (2) and the old on system (1), is 1.075. These results indicate that the insulation-resistance on both systems was so high at the time of observations that both methods gave correct values.

TABLE 2—*Comparisons of observations by new and old methods, using sulfur strain-nsulators with "normal" insulation-resistance, May 23, 1929*

Set No.	System (1)		System (2)		Ratio (1)/(2)
	Reading	Method	Reading	Method	
	volts		*volts*		
1	128	New	118	Old	1.08
2	110	Old	101	New	1.09
3	125	New	115	Old	1.09
4	118	Old	109	New	1.08
5	146	New	137	Old	1.07
6	164	Old	154	New	1.06
7	170	New	160	Old	1.06
8	183	Old	171	New	1.07
9	181	New	170	Old	1.06

In order to test the adequacy of the insulators under more adverse conditions comparisons were also made on June 7, July 9 and 11, during the early morning hours near sunrise when the relative humidity was high and the temperature near the dew-point. System (2) was put up the previous evening so that the insulators on this would be exposed to the weather over night, whereas system (1) was put up in the morning just before beginning observations. The observed time (75° M. M. T.) of sunrise was $4^h\ 50^m$ on June 7 and $5^h\ 05^m$ on July 9 and 11. Psychrometer-readings were also taken at these times in order to determine the dew-point and relative humidity.

The results of these observations are shown in Table 3. It should be noted that in this table the ratios are the inverse of those in Tables 1 and 2. The manner in which these ratios may be expected to vary with time if condensation of moisture on the insulators of system (2) has an appreciable effect upon measurements with the old method, is as follows: Using the new method on system (1) and the old on system (2), the ratio should at first be abnormally low but should increase as the insulators become warmer and drier with the advance of day and should approach the value obtained from measurements made with the two methods interchanged.

As will be seen from an examination for June 7 (Table 3), there is no appreciable change in the ratio and consequently no indication of leak. The small observed variation in ratios may be attributed to experimental error.

The observations of July 9 and 11, however, show that change in ratios which gives definite evidence of leak during the earlier hours. On July 9 a 5 per-cent change in the ratio was observed even though the observations did not begin until after sunrise so that partial improvement of the insulation may have been already effected. In view of this, observations were begun still earlier on July 11. At the outset of these observations the insulation was so defective that system (2) would build up no charge until the Sun had risen, after which the ratio gradually increased from zero to 1.07.

Admittedly, conditions on July 11 were unfavorable. A slight rain (about 0.04 inches) had fallen between 17^h and 21^h on the previous evening. A light fog was present around the building in the morning when the observations were begun lasting until just after sunrise. The surfaces of the insulators were slightly cracked and had not been cleaned recently. The results, on this account, do not establish that such effects occur very generally but they do emphasize the importance of attention to the insulation. The difficulty, however, of ascertaining whether the insulation is adequate for measurement by the usual method is so great that one usually gives the insulation the best attention possible and then trusts to luck. Leaks which are sufficient to permit no charging as in the first two sets on July 11 are of course easily detected. However, due to induction, and to dissipation from the wire, little

can be determined regarding the quality of the insulation when attempting measurements with the wire exposed in the variable field of the atmosphere.

After having done considerable work with the present apparatus there is one criticism felt for it. Since the outer case must be raised to rather high potentials, inadvertently touching the case either with the eyebrow while observing or with other part of the body sometimes results in disagreeable electric shocks. An insulating shield could be provided for the eyepiece of the microscope, although perhaps for other reasons it is desirable to keep the outer case at earth-potential.

TABLE 3—*Observations with both new and old methods during early morning hours*

Date	Set No.	Time		System (1)		System (2)		Ratio (2)/(1)	Rel. Hum.	Temp.	Dew-point
		From	To	Reading	Method	Reading	Method				
1929		h m	h m	volts		volts			%	C°	C°
June 7	1	4 44	5 03	87.2	New	88.7	Old	1.02	81	16	12.8
	2	5 08	5 27	83.3	New	84.7	Old	1.02	85	16	13.3
	3	5 33	5 52	90.4	Old	92.8	New	1.03	..	..	....
	4	5 56	6 15	91.0	New	92.6	Old	1.02	79	18	13.9
	5	6 20	6 39	99.9	New	101.9	Old	1.02	71	20	13.9
	6	6 46	7 05	122.9	Old	124.8	New	1.02	66	21	13.9
	7	7 10	7 26	142.8	New	146.7	Old	1.03	..	..	....
	8	7 55	8 14	178.0	New	181.8	Old	1.02	67	22	15.0
	9	8 23	8 42	170.7	Old	173.7	New	1.02	63	23	16.1
	10	8 51	9 10	151.3	New	156.0	Old	1.03	..	..	....
	11	9 11	9 30	143.8	New	146.3	Old	1.02	55	26	17.2
July 9	1	5 15	5 34	196.7	New	186.5	Old	0.94	91	22.8	21.1
	2	5 35	5 50	231.9	New	227.9	Old	0.98	..	....	....
	3	5 55	6 14	275.9	New	274.4	Old	1.00	82	24.0	20.6
	4	6 55	7 14	247.7	New	247.0	Old	1.00	74	26.0	21.1
	5	7 15	7 34	241.5	New	241.4	Old	1.00	67	28.0	21.1
	6	7 35	7 50	245.5	New	244.4	Old	1.00	61	29.5	21.1
	7	8 34	8 53	204.8	New	206.4	Old	1.01	..	....	....
	8	8 54	9 13	202.1	New	201.2	Old	1.00	58	31.0	22.2
July 11	1	4 00	4 19	80	New	0	Old	0	96	20.5	20.0
	2	4 25	4 38	88	New	0	Old	0	95	20.5	20.0
	3	4 56	5 15	138.6	New	93.3	Old	0.67	89	21.0	18.9
	4	5 18	5 37	154.2	New	146.2	Old	0.95	88	20.6	18.9
	5	5 55	6 14	235.0	New	237.0	Old	1.01	83	21.2	18.9
	6	6 45	7 04	326.5	New	349.2	Old	1.07	76	22.0	17.8

To accomplish this it would be necessary to install guard-rings in the insulators between the fibers and the outer case of the instrument. Then with the outer case connected to the adjustable contactor of the potential divider and to earth, and with the guard-rings connected to the side of the potential divider of the same sign as the potential to be measured, and a suitable potential applied from the batteries to the inner case, then the potential of the fibers could be read by inserting a voltmeter between the outer case and the guard-rings when the potential divider is

adjusted so as to give the proper fiber-deflection. It is thought that the insertion of these guard-rings would be a desirable provision to keep in mind in redesigning a new electrometer.

Although this method of measurement has only been applied to the measurement of air-potentials using the Wulf-type bifilar electrometer or the more sensitive Kolhörster single-loop electrometer, it can obviously be used with quadrant-electrometers and in other applications.

It would of course be highly desirable to embody this method in an automatic recorder of air-potentials. However the schemes for doing this which first come to mind seem a bit too complicated; nevertheless one which offers promise in this respect is receiving detailed consideration by the writers.

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THE RELATIVE FREQUENCY OF THUNDERSTORMS THROUGHOUT THE DAY OVER THE OCEANS AND IN THE TROPICS

By G. R. Wait

The data published on the frequency of thunderstorms throughout the day over the oceans are not plentiful; those available seem to give a maximum during the night hours, particularly between 20 and 4 hours. Humphreys[1] offers an explanation for this observed phenomenon, while Whipple[2] would expect it to occur at another time of the day. The latter believes the observational data are at fault since storms are more easily observable during the night hours. To obtain a record of thunderstorms over the oceans entirely free from Whipple's objection, the hours during which a negative potential was recorded with the potential-gradient recorder have been used (see Table 2). Dr. Humphreys' explanation of maximum of thunderstorm-frequency occurring during the night hours is as follows: "The diurnal temperature-range of the surface usually is but a small fraction of 1°*C*, while that of the atmosphere at from 500 to 1000 meters elevation is several fold as great. Hence those temperature-gradients over the ocean that are favorable to rapid vertical convection are most frequent during the early morning hours, and, therefore, the maximum of ocean-thunderstorms usually occurs between midnight and 4 A. M."

In his investigation on "The association of the diurnal variation of electric potential-gradient in fine weather with the distribution of thunderstorms over the globe," Whipple[2] made use of available information regarding the frequency and distribution of thunderstorms over the globe, but deplored the scarcity of such information,

[1] *J. Frank. Inst.*, v. 178, 1914 (526).
[2] *Q. J. R. Met. Soc.*, v. 55, 1929 (1-17).

particularly over the oceans and in the tropics. In this connection, regarding observations over the oceans, he says: "The diurnal variation in the frequency of thunderstorms should, it might be thought, be easily determined from observations on board ship. The ship's logs give the observations for each watch of four hours and the number of watches in which thunder and lightning are reported can be counted. Few analyses of this sort have been published, however, and the only one covering a long period appears to be that of Meinardus, who discussed the observations for the eastern part of the Indian Ocean." For comparison he also gives data taken from observations made at a lighthouse in northwest Scotland. Whipple objects to such data on the ground that thunder and lightning are more likely to be heard and seen during the night hours. Just as thunderstorms are more likely to occur during the afternoon on land, they are more likely to occur from 4^h to 8^h than between 20^h and 24^h on the oceans. The cases of thunderstorms as recorded in the *Carnegie* logs have been tabulated, and the summary according to watches is given together with the summary from Whipple's article, for the Indian Ocean and the lighthouse in Scotland in Table 1. The same objection that Whipple raised to the data taken over the Indian Ocean and at the lighthouse applies equally well to the *Carnegie* data. Accordingly, the potential-gradient photographic records obtained on the vessel between August 1928 and June 1929 have been examined and a record made of each negative potential recorded and the hour it occurred. It is altogether likely that negative potential occurred on some occasions when there was no thunderstorm, yet, in general the record of one will agree very closely with the record of the other. The summary showing the frequency of cases of negative potential throughout the day is also given in Table 1 as percentage of the total number of watches when the phenomena occurred.

TABLE 1—*Summary showing occurrence of thunderstorms and negative potential-gradient*

Watch	0–4	4–8	8–12	12–16	16–20	20–24
Thunderstorms, Indian Ocean	22.5	15.3	11.4	13.0	16.4	21.4
Thunderstorms, Lighthouse	22.1	15.1	12.9	12.2	16.6	21.1
Thunderstorms, Oceans, *Carnegie*	15.9	26.9	4.4	3.8	3.8	45.1
Negative potential-gradient, *Carnegie*	11.9	16.7	20.2	17.9	21.4	11.9

The number of cases when negative potential-gradient was recorded are only 84 and consequently not sufficiently extensive to warrant drawing definite conclusions from them. They do indicate, however, that Whipple is correct in his claim that the existing data regarding the distribution of thunderstorms throughout the day are unreliable.

Regarding thunderstorms in the tropics, Whipple says "Statistics

giving the number of storms hour by hour are not available for many places in the tropics." He gives a table containing a summary of the frequency of thunderstorms throughout the day at two stations in southern India (Travancore). One of the stations (Agustia) was 6,200 feet above sea-level. Brooks[3] after making an analysis of data from high altitudes, concludes that height has a remarkably small effect in determining the incidences of thunderstorms. One year's records of hourly values of negative potential-gradient at the Huancayo (Peru) Observatory have been summarized, and the results given in Table 2, together with Whipple's table for the relative frequency of thunderstorms at the two Indian stations. There is good agreement between the Huancayo data from potential-gradient records, which would be

TABLE 2—*Comparison thunderstorm-frequency at two Indian stations with that of negative potential-gradient at Huancayo*

Thunder at Trevandrum	6	5	4	1	1	2	13	25	16	13	8	6
Thunder at Agustia	3	3	0	0	2	3	15	36	22	9	5	2
Negative p-g at Huancayo	2.1	1.4	0.8	0.9	0.6	2.5	6.7	9.8	10.0	8.5	4.0	2.2

free from the objection raised by Whipple against thunderstorm-data taken at sea, and the thunderstorm-data taken at the two stations in India.

The following table gives, after Brooks,[3] the annual variation of thunderstorms in Peru. In the second line is given the annual variation of negative potential-gradients at Huancayo, Peru. The general agreement is good between the two sets of data;

TABLE 3—*Annual variation of thunderstorms in Peru and of negative potential-gradient at Huancayo*

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Peru	14.3	12.9	10.8	8.7	3.8	2.8	2.3	4.2	5.6	9.9	11.7	12.9
Huancayo	14.0	14.6	15.8	7.9	3.1	3.5	2.0	4.1	7.9	6.7	10.6	9.9

however the actual maximum in the case of the potential-gradient data comes in March instead of January as is the case with the thunderstorm-data.

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[3]*Geophys. Mem.*, No. 24, 1925.

NOTES

(See also pages 229 and 248)

21. *Association Française pour l'Avancement des Sciences*—The last meeting of the French Association for the Advancement of Sciences was held at Havre in July. In accordance with the custom established during recent years, the Section of Meteorology and Physics of the Globe chose for particular consideration this year all questions bearing on the relations of electromagnetic waves with geophysics and meteorology—a timely topic in view of its general interest and of the increased facilities furnished by the technique of wireless telegraphy permitting individual research in this field.

22. *Cruise VII of the Carnegie*—The *Carnegie* sailed from Yokohama June 24 and arrived at San Francisco July 28. Intercomparisons of magnetic standards of the ship were made with those of the Kakioka Observatory June 13, 14, and 15. Notes on the trip and the magnetic results obtained will be published in the next number of the JOURNAL. A newly-designed, photographically-recording, conductivity-apparatus and a gravity-apparatus of the design of Vening-Meinesz were installed on board before the departure of the *Carnegie*, September 3, on the next leg of the cruise for New Zealand via Hawaii, Samoa, and Australia.

23. *Tucson Magnetic Observatory*—Through cooperation between the United States Coast and Geodetic Survey and the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, it will be possible to start atmospheric-electric observations at the Tucson (Arizona) Magnetic Observatory in the near future. The Coast and Geodetic Survey formerly made observations of this sort at its Cheltenham (Maryland) Observatory as a part of its magnetic work, but the new program will be far more comprehensive and one that could be made possible only through cooperation.

There are two phases of special interest. One is the fact that there will now be a station in the United States which will have satisfactory local conditions, and the second is that it will complete a program of investigation at one place which includes determination of magnetic elements, observations of atmospheric potential-gradient and conductivity, solar observations (at University of Arizona, eight miles away), and measurement of ultraviolet radiation (Tucson Desert Sanitarium, three miles away). This will be one of the most comprehensive geophysical programs at any place in the United States.

24. *Twenty-Fifth Anniversary of the Department of Terrestrial Magnetism*—On August 26, on board the *Carnegie* in San Francisco harbor, the Department of Terrestrial Magnetism of the Carnegie Institution of Washington received invited guests in celebration of the twenty-fifth anniversary of the organization of the Department and of the beginning of the active work of research for which the Carnegie Institution was founded.

The program included brief addresses by Dr. Henry S. Pritchett, Vice-President of the Board of Trustees, by Dr. W. W. Campbell, President of the University of California, by Captain J. P. Ault of the *Carnegie*, and by Dr. Walter S. Adams, Director of the Mount Wilson Observatory. Mr. William B. Storey of the Board of Trustees presided.

The remainder of the day was occupied with explanations by the scientific staff of the apparatus used in conducting the investigations aboard ship and in viewing the exhibits set up to illustrate the current work of the Carnegie Institution and the Department of Terrestrial Magnetism. Opportunity to visit the vessel and to inspect the equipment was afforded the public on the afternoons of August 27 and 28. There were over 2500 visitors on board during the three days.

INDUCTION-COEFFICIENTS FOR MAGNETOMETER-MAGNETS[1]

By H. E. McComb

Abstract—A special apparatus was designed for the investigation of induction-coefficients of magnetometer-magnets by Lamont's method. Maximum accuracy is secured when the vertical distance between magnets is equal to one-half the horizontal distance. Tests were made over wide ranges of horizontal and vertical distances.

If a magnet whose magnetic moment is equal to M is oriented parallel to a magnetic field of unit intensity its moment will be temporarily changed by an amount dM. The ratio of the change dM to the original moment M is called the induction-coefficient h. That is, $h = dM/M$. Then the change dM produced in the moment M by a unit field would be hM and the change produced by a field of intensity H would be hMH. The product hM is treated as a constant μ, called the *induction-factor*. The induction-coefficient may change with time, temperature, intensity of magnetization, and direction of extraneous field. For all practical purposes however it is assumed to be satisfactory to treat the factor μ as a constant over fairly long periods and for all conditions under which observations are usually made.

The present discussion deals with the investigation of the determination of the induction-coefficient by Lamont's method.[2] This method is followed by the United States Coast & Geodetic Survey and is described by Hazard.[3] Briefly stated it consists in using as a deflector the magnet whose induction-coefficient is to be determined. The deflector is attached to a special holder which is mounted on the deflection-bar of a magnetometer. Provision is made for observing deflection-angles with the axis of the deflector vertical in a vertical plane at right-angles to the suspended magnet and with its center at various elevations above and below the center of the latter. Observations may be made at the different horizontal distances marked on the regular deflection-bar on both east and west sides of the magnetometer. The induction-bar as used in these observations is shown in Figures 1 and 2. Provision is made for measuring accurately the elevation of the deflector relative to a horizontal plane through the suspended magnet and for preserving the same horizontal distance between magnets.

The deflector may be attached to the bar with its north end up or down over considerable ranges of horizontal and vertical distances. The magnetic moment of the deflector is increased when the north end is down, by the vertical component of the Earth's field and decreased by practically the same amount when its north end is up. The difference in the deflection-angle for these

[1]Publication approved by the Director of the United States Coast & Geodetic Survey.

[2]J. Lamont, Handbuch des Erdmagnetismus.

[3]D. L. Hazard, Directions for magnetic measurements.

different positions is practically proportional to the induction-coefficient h. The relation between the induction-coefficient h, vertical intensity Z, and the deflection angles u_2 (north end of deflector down) and u_1 (north end of deflector up) is given by the equation[3]

$$h = \tan \frac{1}{2} (u_2 - u_1) / [Z \tan \frac{1}{2} (u_2 + u_1)] \qquad (1)$$

For ordinary magnet-steels the induction-coefficient is a small quantity and for magnet-steels of high coercive force this factor is very small so that the value $(u_2 - u_1)$ is of the order of only a few

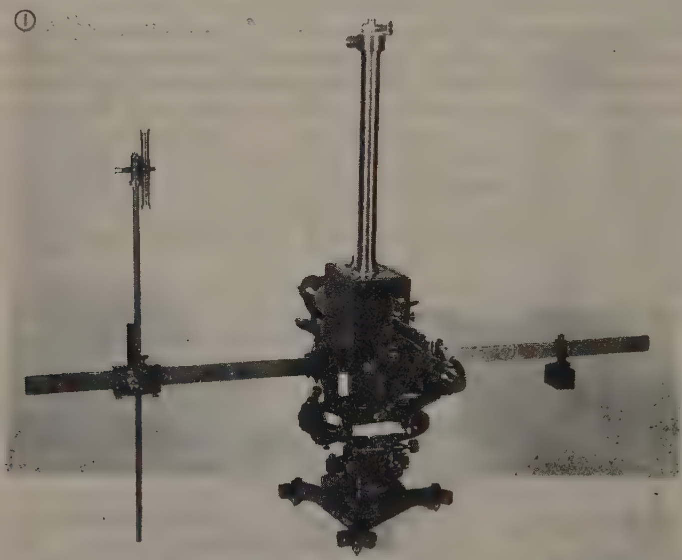


FIG. 1—Inducation-bar as mounted for observing
FIG. 2—Detailed view clamping devices induction-bar

minutes of arc under the conditions where the deflection-angles are maximum. The observations must be made with extreme care in order to secure the desired accuracy.

This investigation was undertaken with the idea of reviewing the method as a whole for the purpose of determining if possible the

conditions for maximum accuracy so that a suitable induction-apparatus might be designed for routine standardization-observations. Accordingly, observations were made over a wide range of vertical distances as well as horizontal distances between magnets. These deflection-distances and deflection-angles are given in Table 1 and plotted in Figure 3. It will be seen that the maximum deflection-angle is reached when the vertical distance between magnets is just one-half the horizontal distance. It is evident also that errors in the vertical distance have least effect on the deflection-angle when this angle is a maximum. The full lines

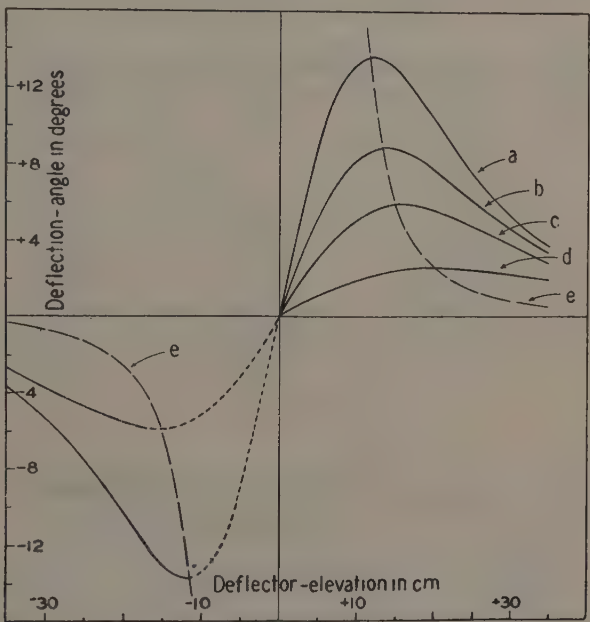


FIG. 3—Variation of deflection-angle with position of deflector (Graphs showing variation for deflection-distances $a=22.5$ cm, $b=26.25$ cm, $c=30$ cm, and $d=40$ cm; e is graph of locus of maxima)

represent actual observations while the dotted lines are interpolations.

It might be mentioned in passing that the induction-apparatus used in these tests was very accurately made. An indication of the degree of precision of the constructional details is shown by the results of the following test made with this apparatus. A deflection-angle was determined with the deflector in a certain position. Then without altering the vertical distance or the position of the deflector relative to the vertical bar, the whole induction-apparatus together with the deflector was removed from the horizontal deflection-bar

and rotated 180 degrees on its vertical axis and then replaced on the bar at the same nominal horizontal deflection-distance and clamped. The suspended magnet came to rest within two minutes of arc of its former position showing that the axis of the deflector passed through the center of the hole on the deflection-bar and incidentally provides a very accurate determination of the horizontal distance between magnets.

In a forthcoming publication George Hartnell of the Cheltenham Magnetic Observatory, derives the following relationship

$$\begin{aligned}\sin u &= [3M/Hd^3]\,[\sin \epsilon \cos \epsilon\,(1+P/d^2)]\\ &= [3M/H]\,[rv/(r^2+v^2)^{5/2}]\,(1+P/d^2) \qquad (2)\end{aligned}$$

in which M is the magnetic moment of the deflector at the temperature of observation; H the horizontal intensity of the Earth's field;

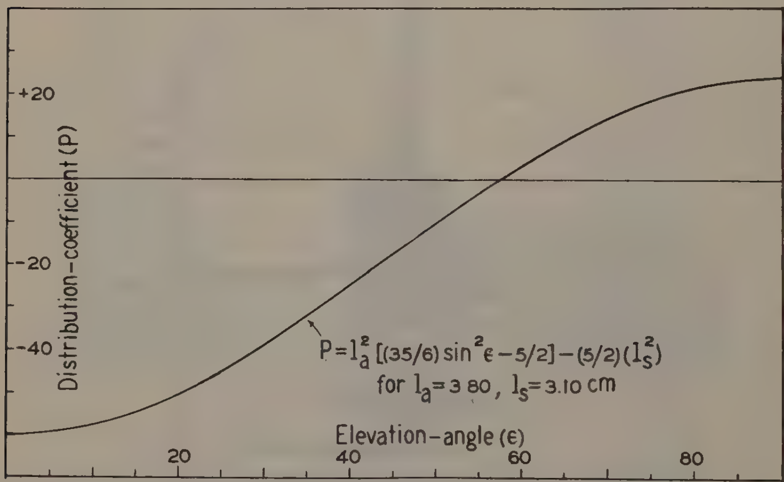


FIG. 4—Variation of distribution-coefficient P with angular elevation of deflector above suspended magnet

ϵ the vertical angle which a line through the centers of the deflecting and suspended magnets makes with the horizontal; r, v, and d the horizontal, vertical, and diagonal distances respectively between magnet-centers; and P a distribution-coefficient depending upon the dimensions of the magnets and the value of the vertical angle ϵ. For the position of the magnets used in the induction-tests, Hartnell finds that

$$P = l^2_a[(35/6)\sin^2 \epsilon - 5/2] - (5/2)l^2_s \qquad (3)$$

in which l_a is one-half the deflector pole-distance (3.80 cm), l_s is one-half the suspended magnet pole-distance (3.10 cm) and ϵ the

TABLE 1—*Variation of deflection-angle with elevation of deflector as used in induction-observations, magnetometer 36, Cheltenham, Maryland*

April 19, 1929 r=22.5 cm		Continued r=22.5		Continued r=26.25		Continued r=30	
d	u	d	u	d	u	d	u
cm	° ′ ″	cm	° ′ ″	cm	° ′ ″	cm	° ′ ″
+35	+3 37 40	−19	−10 56 40	5	5 06 30	−17	−5 51 20
33	4 11 30	−21	−9 45 50	3	3 12 00	−19	−5 41 40
31	4 50 40	−23	−8 35 10	April 24, 1929		−21	−5 24 50
29	5 35 30	−25	−7 30 50	r=30		−23	−5 04 00
27	6 26 40	−27	−6 31 30			−25	−4 41 50
25	7 24 50	−29	−5 39 20	+31	+3 32 30	−27	−4 19 00
23	8 28 40	−31	−4 54 00	29	3 54 30	−29	−3 55 50
21	9 35 50	−33	−4 14 10	27	4 16 30	−31	−3 34 00
19	10 45 50	−35	−3 39 40	25	4 39 40	Sept. 8, 1928	
17	11 57 00	Sept 6, 1928		23	5 01 20	r=40	
15	12 51 40	r=26.25		21	5 19 50		
13	13 27 20			19	5 37 00	+ 3	+0 37 40
12	13 34 50	+35	+3 20 50	17	5 49 30	5	1 01 20
11	13 31 20	30	4 31 35	15	5 51 00	10	1 51 25
9	12 52 10	25	6 01 30	13	5 43 50	15	2 20 40
7	11 21 40	20	7 39 35	11	5 24 30	20	2 31 30
5	8 58 40	15	8 44 35	9	4 51 20	25	2 25 20
+3	+5 47 20	13	8 48 50	7	4 05 10	30	2 10 25
−14	−13 24 00	11	8 33 00	+5	+3 06 00	35	1 52 20
−15	−13 02 00	9	7 52 00	−14	−5 51 40		
−17	−12 04 20	7	6 42 50	−15	−5 54 30		

TABLE 2—*Distribution-coefficients, P, for different positions of magnets in induction-observations, computed from equation* (3)

Deflector-elevation	Distribution-coefficient P	Deflector-elevation	Distribution-coefficient P
°		° ′	
0	−60.12	50	−10.68
5	−59.48	55	− 3.59
10	−57.58	57 39	0.00
15	−54.48	60	+ 3.05
20	−50.26	65	+ 9.08
25	−45.08	70	+14.27
30	−39.06	75	+18.46
35	−32.40	80	+21.60
40	−25.31	85	+23.46
45	−18.00	90	+24.12

TABLE 3—*Deflection-angles and induction-coefficient of magnetometer-magnet 36L at Cheltenham, Maryland, September 8, 1928*

Standard time	Temp.	Horizontal intensity	Vertical dist. (*d*)	Log horizontal distance at 22°	Distribution-coefficient *P*	Deflection-angles From eq. (2)	Deflection-angles Observed	Induction factor μ
h m	°C	*c.g.s.*	*cm*			° ′ ″	° ′ ″	
9 00	21.4	.18624	15	1.47713	−43.27	5 56 26	5 56 12	7.18
9 54	21.6	.18617	14	1.35220	−36.61	13 25 02	13 25 16	7.32
10 45	22.1	.18640	14	1.35220	−36.61	13 23 50	13 23 26	7.64
11 35	22.8	.18657	14	1.41903	−41.46	8 45 52	8 45 52	7.72
13 20	23.6	.18691	14	1.41903	−41.46	8 44 43	8 44 38	7.55
13 44	24.0	.18694	14	1.35220	−36.61	13 20 51	13 20 34	7.82
14 07	24.3	.18709	14	1.35220	−36.61	13 20 06	13 19 29	7.83
14 30	24.6	.18709	14	1.41903	−41.46	8 44 00	8 43 30	7.53
							Mean	7.57

NOTE—In the computation of the deflection-angles in column 7 of the above table, the mean value of log *M* at 20 degrees Cent. was found to be 2.79986. This was determined in the usual manner a short time before the induction observations were made. Log *M* increases 0.000178 for a decrease in temperature of one degree. In April 1929 log *M* was determined again and found to be 2.80158 at 20 degrees.

TABLE 4—*Induction-coefficient observations, long magnet of magnetometer 36, Cheltenham, Maryland, September 8, 1928, for $r=22.5$ cm, $d=14.0$ cm, and $Z=0.54545$*

No.	Position	magnet	North end	Horizontal circle A	Horizontal circle B	Horizontal circle Mean
				° ′ ″	′ ″	° ′ ″
1	E	U	U	104 23 30	23 40	104 23 35
2	E	U	D	77 37 30	37 20	77 37 25
3	E	D	U	77 37 50	37 50	77 37 50
4	E	D	D	104 49 10	49 10	104 49 10
5	W	D	D	77 43 20	43 20	77 43 20
6	W	D	U	104 21 00	21 00	104 21 00
7	W	U	D	104 49 00	49 00	104 49 00
8	W	U	U	77 33 00	33 00	77 33 00

Temperature: 22°.1
Standard Time: 10h 45m

colog Z	0.2632	$2u_1$ (E) = (1−3)	26 45 45
log tan ½ (u_2-u_1)	7.2001	$2u_1$ (W) = (6−8)	26 48 00
log cot ½ (u_2+u_1)	0.6203	Mean	26 46 52
		½ u_1	6 41 43
log h ($h=0.0121$)	8.0836	$2u_2$ (E) = (4−2)	27 11 45
log M	2.7995	$2u_2$ (W) = (7−5)	27 05 40
		Mean	27 08 42
log μ ($\mu=7.64$)	0.8831	½ u_2	6 47 10
		½ (u_2-u_1)	5 27
		½ (u_2+u_1)	13 28 53

vertical angle described above. For the magnets used in these tests this equation reduces to $P=84.23 \sin^2\epsilon-60.12$. Table 2 gives the value of P for this particular pair of magnets and for values of ϵ ranging from 0° to 90°. These are plotted in Figure 4. It is seen that P is negative for all values of ϵ which would be used under ordinary conditions of observation, is zero at approximately 57.5° and is then positive up to 90°. The theoretical values of the deflection-angles computed from equation (2) agree closely with the observed values as shown in Table 3.

As a practical test of the apparatus and the method as a whole the induction-coefficient of the long magnet of magnetometer 36 was determined, using different vertical and horizontal distances. The vertical distances were made as nearly equal to half the horizontal distances as the apparatus would permit. A sample set of observations is given in Table 4 and the values of the induction-factor μ are given in the last column of Table 3.

While small errors in μ produce relatively small errors in the value of HM and eventually come out as instrumental corrections it seems that the induction-coefficients of magnetometer-magnets should be determined at more or less regular intervals not only as a check on possible changes in μ with gradual changes in the magnetic moment or from other causes but as a check on the change in the instrumental correction.

U. S. Coast & Geodetic Survey,
Washington, D. C.,
June 28, 1929

NOTES

(See also pages 229 and 240)

25. *Errata*—Note 11 of the last number of the JOURNAL (page 165) is incorrect in naming *N. H. Heck* as the newly-elected chairman of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union; *D. L. Hazard* was made chairman for the three-year period, July 1, 1929 to June 30, 1932. In the title "Preliminary results of ocean magnetic observations on the *Carnegie* from Callao to Samoa, February to March, 1929," page 117 of this JOURNAL and in reference thereto in the "Contents" on the cover, the word *Tahiti* should be substituted for *Samoa*.

26. *American Astronomical Society*—The forty-second meeting of the American Astronomical Society was held at the Dominion Observatory, Ottawa, Canada, on August 26 to 29, 1929, on the invitation of the Minister of the Interior and the Director of the Observatory. Among the papers presented was one by C. A. French entitled "Terrestrial magnetism in Canada."

27. *Personalia*—Prof. *Henrique Morize* has resigned the post of director of the National Observatory, Rio de Janeiro, which he has held since 1921. He is succeeded by Senhor Sodré da Gama.

Dr. *G. Hellmann*, who retired from the directorship of the Prussian Meteorological Institute in 1922, celebrated his 75th birthday on July 3. The Prussian Ministry for Science, Art, and Education is marking the occasion by the establishment of a "Hellmann Medal," to be awarded to veteran observers at stations of the Prussian Meteorological Service in recognition of long service.

F. E. Wright, of the Geophysical Laboratory, and *W. J. Peters*, of the Department of Terrestrial Magnetism, arrived in San Francisco early in August to install on board the *Carnegie* a Vening-Meinesz gravity-apparatus.

O. H. Gish, of the Department of Terrestrial Magnetism, left Washington on July 21, to join the *Carnegie* at San Francisco to install on board a recording conductivity-apparatus and to inspect the atmospheric-electric work. He plans also to obtain comparisons of the penetrating-radiation apparatus on board with other instruments and will accompany the vessel as far as Honolulu.

J. A. Fleming, Assistant Director of the Department of Terrestrial Magnetism, inspected the *Carnegie* at San Francisco during the week beginning August 19 and in conference with Captain Ault arranged for the future work of the vessel.

Wallace M. Hill, of the United States Coast and Geodetic Survey, is carrying on magnetic field work in the northeastern part of the United States. He will be engaged in this work during the balance of the season.

We regret to learn of the deaths of Dr. *W. G. Duffield*, Director of the Australian Commonwealth Solar Observatory at Mount Stromlo, on August 1, 1929, and of Rear Admiral *Albert Parker Niblack*, U.S.N., President of the International Hydrographic Bureau, at Monte-Carlo on August 28, 1929.

PRELIMINARY RESULTS OF OCEAN MAGNETIC OBSERVATIONS ON THE *CARNEGIE* FROM TAHITI TO SAMOA TO GUAM TO JAPAN, MARCH TO JUNE, 1929[1]

By J. P. Ault, *Commanding the Carnegie*

TABLE 1—*Preliminary Magnetic Results on Cruise VII of Carnegie, Pacific Ocean March to June, 1929*
(*Observers:* J. P. Ault, O. W. Torreson, F. M. Soule, W. E. Scott, L. A. Jones, and J. H. Paul)

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1929	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Mar. 21[c]	16 45 S	209 23	10.6 E	......	......	−0.2	−0.1	0.0	.....	.....	.....	.....	.....	.....
22	17 15 S	208 24	10.7 E	......	......	−0.2	−0.1	0.0	.....	.....	.....	.....	.....	.....
22	17 30 S	208 16	......	31.2 S	.336	.....	.....	.....	−0.1	+0.1	+0.1	+6	+1	+5
22	17 39 S	208 09	10.8 E	......	......	−0.1	−0.1	0.0	.....	.....	.....	.....	.....	.....
23	17 12 S	207 28	10.9 E	......	......	+0.1	−0.2	+0.2	.....	.....	.....	.....	.....	.....
24	16 58 S	206 42	10.6 E	......	......	−0.1	−0.4	0.0	.....	.....	.....	.....	.....	.....
24	16 54 S	206 32	......	30.9 S	.336	.....	.....	.....	−0.5	−0.2	−0.2	+3	−2	+3
24	16 52 S	205 50	10.7 E	......	......	0.0	−0.1	+0.1	.....	.....	.....	.....	.....	.....
25	16 36 S	204 25	10.5 E	......	......	−0.2	−0.2	−0.1	.....	.....	.....	.....	.....	.....
25	16 25 S	203 23	10.5 E	......	......	−0.2	−0.2	0.0	.....	.....	.....	.....	.....	.....
26	16 12 S	202 02	10.4 E	......	......	−0.3	−0.3	−0.1	.....	.....	.....	.....	.....	.....
26	16 10 S	201 54	......	30.1 S	.340	.....	.....	.....	0.0	+0.8	+0.6	+2	−1	+1
27	15 45 S	199 47	10.3 E	......	......	−0.3	−0.2	−0.1	.....	.....	.....	.....	.....	.....
27	15 39 S	199 05	10.5 E	......	......	−0.1	0.0	+0.1	.....	.....	.....	.....	.....	.....
28	15 33 S	198 16	10.1 E	......	......	−0.5	−0.3	−0.3	.....	.....	.....	.....	.....	.....
28	15 33 S	198 10	......	29.8 S	.344	.....	.....	.....	−0.8	+0.1	+0.4	+3	+1	+1
29	15 19 S	196 55	10.4 E	......	......	−0.1	0.0	0.0	.....	.....	.....	.....	.....	.....
29	15 09 S	196 10	10.4 E	......	......	−0.1	+0.1	0.0	.....	.....	.....	.....	.....	.....
30	14 50 S	194 55	10.3 E	......	......	−0.1	−0.1	0.0	.....	.....	.....	.....	.....	.....
30	14 46 S	194 39	......	29.5 S	.347	.....	.....	.....	−1.6	+0.4	+0.4	+1	+1	−1
30	14 42 S	193 48	10.4 E	......	......	0.0	0.0	+0.1	.....	.....	.....	.....	.....	.....
31	14 41 S	192 29	10.5 E	......	......	+0.1	+0.1	+0.2	.....	.....	.....	.....	.....	.....
31	14 41 S	191 39	10.5 E	......	......	+0.1	+0.1	+0.2	.....	.....	.....	.....	.....	.....
Apr. 1	14 32 S	190 28	10.3 E	......	......	0.0	−0.1	+0.1	.....	.....	.....	.....	.....	.....
1	14 29 S	190 14	......	29.0 S	.347	.....	.....	.....	−0.7	+1.1	+1.2	−1	−2	−2
1	14 20 S	189 34	10.5 E	......	......	+0.2	+0.1	+0.3	.....	.....	.....	.....	.....	.....
20[d]	13 30 S	188 18	10.2 E	......	......	+0.1	+0.1	0.0	.....	.....	.....	.....	.....	.....
21	12 50 S	188 15	10.1 E	......	......	+0.1	+0.1	0.0	.....	.....	.....	.....	.....	.....
23	11 45 S	188 11	10.0 E	......	......	0.0	+0.2	+0.1	.....	.....	.....	.....	.....	.....
23	11 35 S	188 15	......	24.6 S	.358	.....	.....	.....	−0.7	+0.2	0.0	+6	+6	+5
24	8 56 S	189 05	9.3 E	......	......	−0.3	0.0	−0.2	.....	.....	.....	.....	.....	.....
24	8 20 S	188 45	9.5 E	......	......	0.0	+0.2	+0.1	.....	.....	.....	.....	.....	.....
25	7 58 S	188 12	9.4 E	......	......	0.0	+0.2	+0.1	.....	.....	.....	.....	.....	.....
25	7 53 S	188 11	......	......	.358	.....	.....	.....	.....	.....	.....	+3	+3	+3

[a]Charts used for comparison: U. S. Hydrographic Office charts 1700, 1701, and 2406 for 1925; British Admiralty charts 3776 and 3777 for 1927, 3598 and 3603 for 1922; Reichs-Marine-Amt. charts Tit. XIV, 2, 2a, and 2b for 1920. All chart-values have been corrected to 1929.2 on account of secular-change rate indicated by the respective charts. The chart-differences are obtained by subtracting the chart-values from those determined on the *Carnegie*, east declination, north inclination, and horizontal intensity being reckoned as positive and west declination and south inclination as negative.

[b]Expressed in units of third decimal C. G. S.

[c]The *Carnegie* was at Papeete, Tahiti during March 13 to 20, 1929.

[d]The *Carnegie* was at Pago Pago, Samoa during April 1 to 5 and at Apia, Samoa during April 6 to 20, 1929.

[e]May 6 omitted on account of crossing 180th meridian.

[f]The *Carnegie* was at Guam during May 20 to 25, 1929.

[1]For previous values obtained on Cruise VII, see *Terr. Mag.*, v. 33, pp. 121-128, 189-194, and v. 34, pp. 23-31, 117-121.

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity		
			D	I	H	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U.
1929	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
Apr. 25	7 48 S	188 11	.....	18.1 S	.....	.....	.....	.....	−0.9	−0.7	−0.8	.....	.....	.....
25	7 14 S	188 02	9.8 E	.....	.....	+0.4	+0.6	+0.6	.....	.....	.....	.....	.....	.....
26	6 46 S	187 39	9.4 E	.....	.....	+0.1	+0.2	+0.2	.....	.....	.....	.....	.....	.....
26	6 19 S	187 35	9.3 E	.....	.....	+0.1	+0.2	+0.1	.....	.....	.....	.....	.....	.....
27	5 24 S	187 36	9.2 E	.....	.....	+0.1	+0.2	0.0	.....	.....	.....	.....	.....	.....
27	5 20 S	187 36	.....	12.3 S	.360	.....	.....	.....	+0.2	+0.2	0.0	+5	+6	+
27	4 49 S	187 34	9.3 E	.....	.....	+0.3	+0.3	+0.4	.....	.....	.....	.....	.....	.....
28	3 54 S	187 24	9.1 E	.....	.....	+0.2	+0.3	+0.3	.....	.....	.....	.....	.....	.....
28	3 23 S	187 12	9.3 E	.....	.....	+0.4	+0.5	+0.5	.....	.....	.....	.....	.....	.....
29	2 21 S	186 36	9.2 E	.....	.....	+0.4	+0.5	+0.5	.....	.....	.....	.....	.....	.....
29	2 04 S	186 33	.....	5.9 S	.356	.....	.....	.....	+0.3	+0.5	+0.8	+4	+5	+
29	1 14 S	186 24	9.2 E	.....	.....	+0.5	+0.4	+0.7	.....	.....	.....	.....	.....	.....
30	0 05 N	186 06	9.3 E	.....	.....	+0.7	+0.5	+0.8	.....	.....	.....	.....	.....	.....
30	0 54 N	185 46	9.1 E	.....	.....	+0.5	+0.2	+0.5	.....	.....	.....	.....	.....	.....
May 1	2 04 N	185 07	9.4 E	.....	.....	+0.9	+0.4	+0.9	.....	.....	.....	.....	.....	.....
1	2 41 N	184 47	.....	2.8 N	.347	.....	.....	.....	−0.2	+0.3	−0.7	+6	+7	.....
1	2 57 N	184 36	9.2 E	.....	.....	+0.6	+0.2	+0.7	.....	.....	.....	.....	.....	.....
2	4 14 N	183 46	9.1 E	.....	.....	+0.4	0.0	+0.5	.....	.....	.....	.....	.....	.....
3	5 53 N	182 43	9.4 E	.....	.....	+0.7	+0.2	+0.7	.....	.....	.....	.....	.....	.....
3	6 12 N	182 30	.....	9.6 N	.338	.....	.....	.....	+0.6	+0.3	+1.3	+5	+5	−
3	6 59 N	181 57	9.1 E	.....	.....	+0.3	0.0	+0.3	.....	.....	.....	.....	.....	.....
4	7 59 N	181 17	9.4 E	.....	.....	+0.5	+0.3	+0.5	.....	.....	.....	.....	.....	.....
5	10 07 N	179 50	9.6 E	.....	.....	+0.6	+0.6	+0.6	.....	.....	.....	.....	.....	.....
5	10 26 N	179 38	.....	16.4 N	.326	.....	.....	.....	+0.1	−0.2	+0.2	+3	+4	−
5	11 29 N	178 57	9.4 E	.....	.....	+0.4	+0.4	+0.4	.....	.....	.....	.....	.....	.....
7▪	13 09 N	177 41	9.6 E	.....	.....	+0.7	+0.7	+0.6	.....	.....	.....	.....	.....	.....
7	13 59 N	176 47	9.7 E	.....	.....	+1.1	+0.9	+0.7	.....	.....	.....	.....	.....	.....
8	15 05 N	175 23	8.9 E	.....	.....	+0.6	+0.2	0.0	.....	.....	.....	.....	.....	.....
8	15 16 N	175 03	.....	23.3 N	.312	.....	.....	.....	−0.3	+0.2	+0.6	+1	+1	+1
8	15 38 N	174 03	9.0 E	.....	.....	+0.9	+0.5	+0.4	.....	.....	.....	.....	.....	.....
9	16 20 N	172 17	8.4 E	.....	.....	+0.7	+0.4	+0.1	.....	.....	.....	.....	.....	.....
9	16 56 N	171 13	8.3 E	.....	.....	+0.9	+0.4	+0.3	.....	.....	.....	.....	.....	.....
10	18 06 N	169 42	7.7 E	.....	.....	+0.7	+0.4	+0.2	.....	.....	.....	.....	.....	.....
10	18 34 N	168 44	.....	26.0 N	.309	.....	.....	.....	−0.9	−0.9	−0.1	+2	+2	+2
10	18 41 N	168 23	7.1 E	.....	.....	+0.5	+0.1	0.0	.....	.....	.....	.....	.....	.....
11	19 13 N	167 01	6.8 E	.....	.....	+0.6	+0.4	+0.2	.....	.....	.....	.....	.....	.....
11	19 30 N	165 58	7.2 E	.....	.....	+1.3	+1.3	+1.0	.....	.....	.....	.....	.....	.....
12	20 16 N	164 03	.....	27.6 N	.304	.....	.....	.....	−1.2	−0.2	+0.3	−2	−3	−3
12	20 16 N	163 04	5.0 E	.....	.....	+0.1	+0.1	−0.3	.....	.....	.....	.....	.....	.....
13	20 13 N	161 33	4.6 E	.....	.....	+0.3	+0.2	−0.2	.....	.....	.....	.....	.....	.....
13	20 13 N	160 30	4.7 E	.....	.....	+0.7	+0.6	+0.2	.....	.....	.....	.....	.....	.....
14	19 52 N	159 04	4.1 E	.....	.....	+0.4	+0.3	0.0	.....	.....	.....	.....	.....	.....
14	19 42 N	158 47	.....	25.7 N	.318	.....	.....	.....	+0.3	0.0	0.0	+4	+3	+4
14	19 14 N	157 45	3.7 E	.....	.....	−0.6	+0.2	−0.2	.....	.....	.....	.....	.....	.....
15	18 44 N	156 24	3.3 E	.....	.....	+0.2	0.0	−0.3	.....	.....	.....	.....	.....	.....
15	18 21 N	155 21	3.1 E	.....	.....	+0.2	+0.1	−0.2	.....	.....	.....	.....	.....	.....
16	17 45 N	153 58	2.8 E	.....	.....	+0.1	−0.1	−0.3	.....	.....	.....	.....	.....	.....
16	17 35 N	153 39	.....	21.6 N	.329	.....	.....	.....	−1.2	+0.5	+0.3	+5	+3	+3
16	17 09 N	152 50	2.7 E	.....	.....	+0.3	0.0	−0.2	.....	.....	.....	.....	.....	.....
17	16 20 N	151 18	2.5 E	.....	.....	+0.2	0.0	−0.2	.....	.....	.....	.....	.....	.....
17	15 49 N	150 13	2.3 E	.....	.....	+0.1	−0.1	−0.2	.....	.....	.....	.....	.....	.....
18	15 11 N	148 51	2.1 E	.....	.....	+0.1	−0.1	0.0	.....	.....	.....	.....	.....	.....

Date	Latitude	Longitude east	*Carnegie*-values D	*Carnegie*-values I	*Carnegie*-values H	Chart-differences[a] Declination Br.	Declination Ger.	Declination U. S.	Inclination Br.	Inclination Ger.	Inclination U. S.	Hor. intensity[b] Br.	Hor. intensity Ger.	Hor. intensity U. S.
1929	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
ay 18	14 46 N	147 59	......	16.4 N	.343	.....	.....	.....	−0.2	+0.1	+0.5	+3	+4	+3
18	14 36 N	147 37	2.0 E	......	......	+0.1	0.0	0.0	.....	.....	.....	.....	.....	.....
19	14 08 N	146 17	2.0 E	......	......	+0.1	+0.1	+0.1	.....	.....	.....	.....	.....	.....
25[f]	13 49 N	144 32	1.7 E	......	......	0.0	−0.1	−0.1	.....	.....	.....	.....	.....	.....
26	15 22 N	144 12	1.1 E	......	......	−0.1	−0.1	−0.3	.....	.....	.....	.....	.....	.....
26	15 43 N	144 09	......	17.9 N	.347	.....	.....	.....	0.0	0.0	+0.5	+3	+3	+2
26	16 46 N	144 05	1.0 E	......	......	+0.1	0.0	0.0	.....	.....	.....	.....	.....	.....
27	18 12 N	144 03	0.5 E	......	......	+0.1	+0.1	−0.1	.....	.....	.....	.....	.....	.....
27	19 16 N	144 00	0.3 E	......	......	+0.1	+0.3	−0.1	.....	.....	.....	.....	.....	.....
28	20 49 N	144 07	0.2 E	......	......	+0.3	+0.4	+0.2	.....	.....	.....	.....	.....	.....
28	21 44 N	144 13	......	28.3 N	.334	.....	.....	.....	−0.5	+0.4	−0.2	+4	+4	+6
28	21 59 N	144 14	0.7W	......	......	−0.2	−0.2	−0.4	.....	.....	.....	.....	.....	.....
29	23 07 N	144 12	1.0W	......	......	−0.2	−0.1	−0.3	.....	.....	.....	.....	.....	.....
29	23 52 N	144 00	1.1W	......	......	−0.1	0.0	−0.1	.....	.....	.....	.....	.....	.....
30	24 50 N	144 02	1.6W	......	......	−0.4	−0.2	−0.3	.....	.....	.....	.....	.....	.....
30	25 04 N	144 04	......	34.1 N	.325	.....	.....	.....	+0.2	+0.1	+0.2	+5	+2	+5
30	25 34 N	144 12	1.2W	......	......	+0.2	+0.4	+0.3	.....	.....	.....	.....	.....	.....
31	26 12 N	144 23	1.7W	......	......	−0.1	+0.1	0.0	.....	.....	.....	.....	.....	.....
ne 1	27 59 N	144 04	2.6W	......	......	−0.4	−0.2	−0.3	.....	.....	.....	.....	.....	.....
1	28 12 N	144 01	......	38.5 N	.318	.....	.....	.....	−0.2	−0.3	0.0	+6	+3	+5
1	28 55 N	143 52	2.6W	......	......	−0.1	+0.2	+0.1	.....	.....	.....	.....	.....	.....
2	30 00 N	143 58	3.3W	......	......	−0.3	−0.2	−0.3	.....	.....	.....	.....	.....	.....
2	30 05 N	143 55	......	41.1 N	.315	.....	.....	.....	+0.1	−0.2	+0.2	+8	+6	+8
2	30 28 N	144 16	2.9W	......	......	+0.2	+0.3	+0.2	.....	.....	.....	.....	.....	.....
3	30 52 N	144 19	3.5W	......	......	−0.4	−0.2	−0.3	.....	.....	.....	.....	.....	.....
4	32 11 N	142 53	4.2W	......	......	−0.2	0.0	−0.3	.....	.....	.....	.....	.....	.....
4	32 30 N	142 28	......	44.6 N	.308	.....	.....	.....	+0.5	+0.4	+0.7	+7	+4	+6
4	32 58 N	141 55	4.7W	......	......	−0.3	−0.3	−0.4	.....	.....	.....	.....	.....	.....
5	33 41 N	141 20	5.0W	......	......	−0.2	−0.2	−0.4	.....	.....	.....	.....	.....	.....

Notes on Trip From Tahiti to Pago Pago and Apia, Samoa, March 20 to April 6, 1929

The *Carnegie* left Papeete at 15^h 35^m on March 20 under her own power, heading to the northward of Moorea. The next day the wind hauled ahead and we were obliged to proceed southward of Huaheine and Raiatea Islands. Soundings showed new shoals south of this group, as also south of Mapehaa Island, farther to the westward. Before the western islands of the Society Group were cleared, it was necessary to use the engine on several occasions on account of light and variable winds. The engine was operated also for three days continuously before arriving at Pago Pago on April 1 at 19^h 30^m. The easterly trade-wind was entered March 24, and this breeze continued until March 28. The usual program of work was carried out daily.

Considerable time was spent in trying to operate the new Coast and Geodetic Survey sounding-machine, which had been installed on the port side of the quarterdeck, aft near the meteorological shelter-house, during the stay in Papeete. The machine is

built so that the drum is floating and must be moved along its axis to engage either the brake or the clutch. When the vessel rolls, the tension on the brake is changed by the movement of the drum so that the speed of paying out cannot be kept under control. When paying out on the clutch, letting the weight of the snapper-type bottom-sampler unreel the drum against the motor, the momentum of the drum becomes too great for the speed at which the snapper is going down and the wire slackens and kinks. To stop it, the drum must be moved away from the clutch, through neutral or no control, across to engage the brake, and hence is stopped with a jerk which parts the wire. The drum as received did not hold more than 4,700 meters of wire; while in Apia it was machined out to hold 7,000 meters. This experimental work was very expensive of bottom-samplers and wire, so that no bottom-samples were obtained during this part of the trip.

On March 26 one of the air-tanks in the engine-room exploded, the end breaking through the bulkhead into the gasoline tank-room, while the air-tank jumped aft, out of its cradle and landed against the air-compressor. Fortunately no one was injured and none of the instrumental equipment was seriously damaged, outside of the parting of several electric cables. The compressor was operating, but the relief or safety-valve was in good working order apparently, so it was not a case of overcharge but of weakness in the tank.

The following observations were made: 20 declination, 6 inclination and intensity, 6 ocean-stations, 70 sonic depths, 10 pilot-balloons, daily atmospheric-electric observations and one diurnal-variation run, and two evaporation-series.

After taking on gasoline, oil, and kerosene at Pago Pago, the *Carnegie* left for Apia April 5, arriving the next morning, going the entire distance under engine-power.

Notes on Trip From Apia to Guam and to Yokohama, April 20 to June 7, 1929

After completing the work of intercomparing magnetic instruments with those of the Apia Observatory, standardizing deflector 5, and carrying out simultaneous ship and shore potential-gradient observations, the ship sailed from Apia April 20 en route for Guam and proceeded northward toward the Union Islands, with light and variable winds. When only 65 miles from Apia, two stowaways came on deck out of the forepeak. It was decided to return to Apia and land the boys back home to avoid later trouble and expense, since there was no place for them on board.

Soon after leaving Apia the second time, the wind became favorable and the engine was stopped. During the following week the winds were variable and calms were frequent until April 28, when the northeast trade-wind began. This breeze continued without interruption until Guam was reached May 20. The regular daily program was carried out in spite of frequent rain-

squalls, which, however, were usually of short duration. The date May 6 was omitted due to crossing the 180th meridian of longitude.

Wake Island was sighted early on May 11, and passed within one-quarter mile of Peacock Point, the southeast point of the Island. Observations checked the position given for the island by the U. S. S. *Tananger* Expedition of 1923. The highest point is only 21 feet above sea-level; there are no cocoanut trees, only low-spreading umbrella trees and shrubs. Numerous birds were flying about. No signs of life or of buildings were seen. Glimpses of the beautiful green-blue lagoon seen through the break in the south side showed a considerable area free from obstructions, which might make a suitable harbor and landing for seaplanes.

Rota and Guam islands were sighted on May 19, and the vessel was safely moored in Port Apra early on May 20.

Between Apia and Guam the following observations were made: 48 declination, 13 inclination and horizontal intensity, 14 oceanic stations, 20 pilot-balloon flights, 3 atmospheric-electric runs, 22 potential-gradient traces, 159 sonic depths, and 3 bottom-samples.

After several further attempts to use the new Coast and Geodetic Survey sounding-machine, it was decided to resume use of the winch as before for getting bottom-samples. As indicated in the previous report, the construction is such that the machine cannot be readily controlled when mounted, as it is on the *Carnegie*, with reel axle athwartships. On April 24 the 4-mm aluminum-bronze cable failed in seven or eight places, the heart strands breaking near the points where water-bottles were usually clamped. This wire has been in use since leaving Balboa in October, 1928. It was necessary to discard about 2,700 meters. With over 4,000 meters of wire out, 120-pound lead weight on the end, and seven or eight bottles in series, the strain on the wire is very great, especially with any current. On the same day, difficulty in controlling new sounding-machine caused a break in the piano wire and loss of snapper No. 7. The piano wire was shifted to the winch on April 25, but owing to shortage of snappers no bottom-samples were secured after April 28 until en route from Guam to Japan.

On April 28 the messenger caught in a jelly-fish and deep series had to be repeated. On April 30 the messenger-chain caught under the wire-guide on one bottle and deep series had to be repeated. On May 2 the vessel was rolling and surging so heavily that piano wire fouled bottle-wire and came up all entangled. Seven hours were required to untangle the wires and finish the station, and 2,000 meters of piano wire were lost. The deep series had to be repeated three times due to accidental interference with messengers, etc. In order to have at least 3,000 meters of bottle wire, it was necessary to splice on 1,100 meters remaining from the wire used in the Atlantic. This made it necessary to use one messenger on a long chain to clear the splice. Bottle *M* was attached above the splice and its messenger, hanging on long

chain, was attached below the splice. This chain later was replaced by a wire to avoid trouble due to chain catching on parts of the bottle.

When attempting to get a bottom-sample on May 9 the usual 50-pound weight was used with the snapper. However, the vessel was drifting with wind and current so rapidly that the angle soon reached 75° and the attempt was abandoned. It was decided to experiment with heavier weights to be detached when the snapper struck bottom. The Sigsbee releasing-device was removed from the tube and attached to the end of snapper-rod. Apparently the arrangement should function, but, unfortunately, the splice parted where the drift-line was attached to the piano wire. The weights used, 120 pounds, were too heavy. It is intended to use this scheme after suitable weights and snappers are made in Japan.

The sonic depth-finder results were of unusual interest in that we crossed over many shoals and deeps, showing a generally mountainous region on the ocean-floor. One region varied in depth from 6,500 meters to 4,000 meters and back to 5,700 meters. Another varied from 5,600 meters to 1,340, to 5,130 meters, 1,900 meters, and back to 5,800 meters. Two days before reaching Guam, at 14° 32′ north, 147° 28′ east, the depth was 8,060 meters, the previous depth, 20 miles northeast, being 2,892 meters. This is the northeast end of Nero Deep.

During the five-days' stay in Guam the old 4-mm aluminum-bronze cable was removed from the reel and the new wire, 6,000 meters, received at Callao was installed. Six new weights were cast for use with Sigsbee sounding-tube and the exhaust pipe for the Buffalo engine was brazed where cracked.

The magnetic station at Sumay was reoccupied. The stay was all too brief but was much enjoyed through the very generous hospitality which was extended by Governor and Mrs. Shapley, and the Navy and Marine personnel, as also by Superintendent Mullahey of the Cable Station, who placed his home and his car, with himself as chauffeur, at the disposal of the party.

After taking on fresh water and gasoline, sail was set for Yokohama on May 25, keeping the easterly trade-wind for four days and making good daily runs. The wind then shifted to the south and varied between southeast and southwest until June 2. The positions of a typhoon were received on the night of June 1 by radio from the Manila Observatory through amateur station K1AF for the two preceding days. The wind had been increasing in force all afternoon and the sea was becoming heavier. We at once plotted these positions on the chart and predicted the path which the storm-center would follow. By rough estimation of its rate of travel, it seemed due to intercept the *Carnegie's* track within a few hours. The barometer had dropped four millimeters during the preceding eight hours and it seemed wise to head east by south and place the vessel in a safer position, to avoid the path of the storm. After running eastward for two hours, the barometer

began to rise and the wind moderated so we hove the vessel to and waited for wind and sea to moderate further. After another wait for two hours course was again set toward the northwest, the vessel riding on the tail of the typhoon. The wind continued to shift to the right, showing that the storm had passed on to the eastward. We got a great thrill out of this first experience in handling a storm by radio, and everything worked out like clockwork and exactly as predicted from information received within the hour by radio.

There followed four days of rough sea, contrary winds, and engine running. When within fifteen miles of the entrance to Tokio Bay, on Wednesday night, June 5, a rapidly falling barometer and rainy threatening weather made it necessary to heave the vessel to in order to judge the nature of the storm and to see the headland. After waiting two hours, conditions became worse and it was decided to get off shore to increase the margin of safety. After running the engine five hours, the wind and sea had risen to such an extent that we had to heave the vessel to and ride out the typhoon when about twenty miles off shore and apparently near the center of the oncoming typhoon. About noon, the barometer appeared to reach its lowest point and became steady. The wind began to moderate and back from south toward west, the storm-center apparently having passed to the west and north. Two sails were lost and several minor accidents happened on deck, but the vessel rode through the heavy seas in good order. By early Friday morning the sea had moderated and the wind had shifted to northeast. Sail was set and by 11^{h} Tokio Bay was entered, the vessel going up to Yokohama under engine-power and arriving at $19^{h} 45^{m}$. The Thursday radio report from Manila gave the typhoon-center a position 10 miles north of the vessel on Thursday noon.

The following observations were made while en route from Guam to Yokohama: 21 declination, 6 inclination and horizontal-intensity stations, 5 ocean-stations, 5 bottom-samples, 50 sonic depths, one atmospheric-electric run, 9 pilot-balloon flights, and 4 bottom-temperatures.

With the sonic depth-finder a new deep was discovered on May 29 at 23°.8 north, 144°.1 east, and was named Fleming Deep, in honor of J. A. Fleming, the Assistant Director of the Department. The greatest depth observed was 8,650 meters. This Deep was traversed in a south to north true direction and was nine miles wide at 8,600 meters, 20 miles at 8,000 meters, 34 at 7,000 meters, 47 at 6,000 meters, 74 at 5,000 meters, 106 at 4,000 meters, and 162 miles wide at 3,000 meters. Only five localities are known to be deeper than the Fleming Deep, namely, Kermadec, Guam, Philippines, Juril Islands, and off the southern islands of Japan.

Bottom-samples were secured at each of the five ocean-stations with the new cable and sounding-tube installed at Guam. At Station No. 111, 6,385 meters of piano wire were paid out before bottom was reached.

The second Coast and Geodetic Survey propeller reversing-frame was modified to hold two Richter and Wiese thermometers, and this frame, called *Z2*, was used at the last four stations. Bottom temperatures were secured at these four stations and at the last three the depth was determined by means of an unprotected thermometer in connection with one protected thermometer.

The Japan Stream was entered on June 4, at $19^h\ 30^m$ at 33°.0 north, 141°.8 east. The temperature began to rise suddenly and in twelve hours it had risen three degrees.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON,
Washington, D. C.

LETTERS TO EDITOR

PROVISIONAL SUNSPOT-NUMBERS FOR APRIL TO JUNE, 1929

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	April	May	June	Day	April	May	June
1	47	65[a]	27	17	*M*47[ac]	53	64[aa]
2	51	94	30	18	50[a]	47[a]	76[dd]
3	46	*M*88[bc]	26	19	58	28	70[a]
4	32	74[a]	*W*47[cd]	20	*E* 62[c]	32[a]	91
5	....	74	54	21	....	30	*M*101[c]
6	*M*63[ca]	83	....	22	47	34[d]	110[d]
7	54[a]	*E* 71[c]	....	23	48	30	104
8	61[b]	79[d]	68	24	36	*E* 49[c]	84[bb]
9	65[d]	....	58[b]	25	40[d]	61	80[a]
10	*M*76[c]	62[aa]	68[a]	26	44	59[a]	85
11	..[d]	52	82	27	43	59	62
12	73	48	88[a]	28	36[d]	59[b]	*E* 65[ac]
13	59[d]	76	84	29	*E* 38[cc]	35	*E* 79
14	71	71[a]	79	30	53	35	84[d]
15	59[a]	73	*M*80[c]	31		34	
16	62	*E* 73[cc]	*M*76[c]				
				Means	52.6	57.6	72.2
				No. days	27	30	28

Mean, April to June, 1929: 60.8 (85 days)

[a]Passage of an average-sized group through the central meridian.
[b]Passage of a larger group through the central meridian.
[c]New formation of a large or average-sized center-of-spot activity: *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, near the central meridian.
[d]Entrance of a large or average-sized center of activity on the east limb.

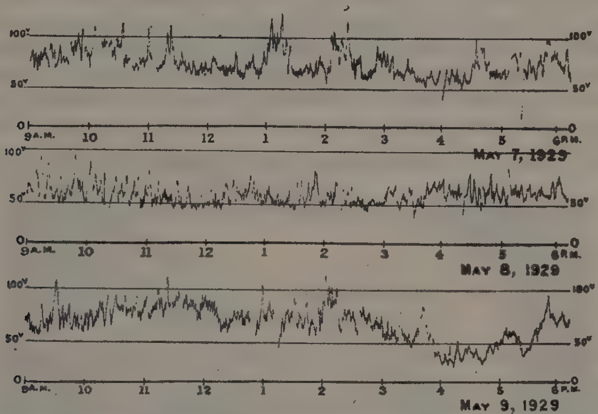
Zürich, Switzerland W. BRUNNER

ATMOSPHERIC POTENTIAL-GRADIENT RESULTS AT CEBU DURING SOLAR ECLIPSE, MAY 9, 1929

The accompanying figure is a reproduction of the atmospheric-electric curves taken with the Wulf electrometer of the Weather Bureau, Central Office, Manila, at Sogod, Cebu, Philippine Islands, on the day of the total eclipse of the Sun, May 9, 1929, together with the two curves for the days preceding.

First contact was calculated as $14^h\ 10^m\ 29^s$ and was correct practically to the second; totality began at $15^h\ 29^m\ 47^s$ and lasted for 3 minutes and 38 seconds; last contact was at $16^h\ 42^m\ 7^s$.

It will be noticed that while for the two days preceding the eclipse, days that were comparatively normal, the curve keeps to a pretty even keel, on the afternoon of the eclipse there is a deep trough from about 14^h to 18^h. Also there is a slight minimum at



POTENTIAL GRADIENT, ATMOSPHERIC ELECTRICITY ON DAY OF TOTAL ECLIPSE OF SUN, MAY 9, 1929, SOGOD, CEBU, P. I, WITH COMPARISON RECORDS FOR MAY 7 AND 8, 1929

almost exactly the time of the totality. On the face of it, this would look something like a "night-effect," that is, the usual lowering of potential gradient at night upon the withdrawal of the Sun's ionizing effect. But there is a fly in the ointment and a big fly at that, namely, clouds. Rather slight cirro-stratus at the time of first contact rapidly developed to more decided cloudiness as the eclipse proceeded. In fact, the clouds at totality were so pronounced that they spoiled practically all pictures of the corona, and the corona was completely hidden during the last forty seconds or so of totality. The clouds persisted until the evening, when they cleared away. It seems probable that the cooling of the air, as the Sun's heat was withdrawn, condensed the moisture in the air.

My judgment then is that while interesting, these atmospheric-electric records can by no means be taken as proof of an effect due to the eclipse itself; it may well be, as can easily be seen, an effect

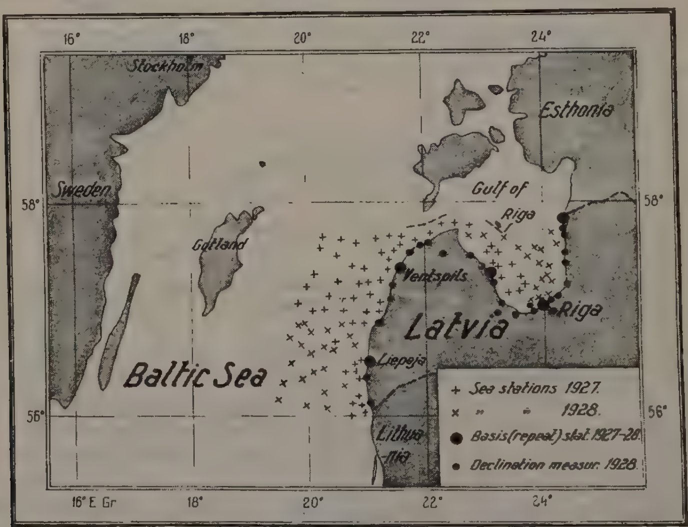
due to the cloudiness. It is thought that the same kind of experiment should be made at future eclipses. A convincing proof of effect or no effect must be taken on an eclipse day that is "normal" in all respects. Records were taken continuously for two weeks preceding the eclipse, but the weather was not normal enough to make out a reliable "normal" curve for the station.

C. E. Deppermann, S. J.

Manila, June 11, 1929

MAGNETIC WORK ON THE LATVIAN COAST AND THE BALTIC SEA, 1927-1928

The Baltic Sea is known to be much disturbed magnetically. Measurements made on the coast while giving, of course, only the general picture, indicated some local perturbations. Progress in the magnetic investigation of the Baltic Sea is being made by the survey-work of the Esthonian non-magnetic yacht *Cecilie*[1]. Such measurements by the *Cecilie* were also made on the coast of Latvia in the years 1927 to 1928. Only a few magnetic measurements had been made previously on the coast. The latest



of these were made in 1911 to 1912 by the Russian magneticians, N. Trubjatchinsky[2] (along Gulf of Riga and the coast of the Baltic Sea) and M. Kamensky[3] (in Liepaja—Libau).

[1] A. v. Gernet, Überblick über den Gang der magnetischen Vermessung der Ostsee. Zs. Geophysik, Braunschweig, v. 4, 1928 (27-33).

[2] N. Trubjatchinsky, Magnetic measurements on the coast of Baltic Sea made in 1911 and 1912 (Russian). Sapiski po Gidrografii, v. 51, Leningrad, 1926.

[3] M. Kamensky, The isogonic lines in the environs of Libava (Russian). Ibidem, v. 39 and 40, Petrograd, 1917.

Some declination-measurements for use in practical navigation had been made in 1921 and 1923 by A. Schaggers and L. Slaucitajs[4]. With the year 1927 there was begun a systematic work on sea and coast, which was completed in the autumn of 1928. On the coast, using a Sartorius-Tesdorpf theodolite, measurements were made at five repeat-stations (D, H, I). Thirty measurements of declination were made on the coast (in winter also on the sea, covered with ice, near the coast) with a Neumayer-Schmidt declinometer. The yacht *Cecilie* measured D, H, and Z at 102 points (see the accompanying chart). The measurements on board the *Cecilie* were made by A. v. Gernet; those for D on the coast were made by the writer as the representative of the Latvian Marine Department. After revision the results will be published early in 1930. It is interesting to note that in so small a region there are to be found such noticeable changes in the elements; thus the values of declination vary from about 4° west to about 3° east. The agonic line at present crosses the coast of Riga Gulf to the west of Riga (near Kemeri) and continues in a north-north-east direction across the Gulf. The average declination at the meridian 20° from Greenwich is about 2° west and at the meridian 24° about 1° east. Not far from the coast near Riga and in other places some local declination-anomalies reaching 3° and 4° were found in comparatively small areas.

L. SLAUCITAJS, *Assistant, Latvian University*

Riga, 1929

IONS AND ELECTRICAL CURRENTS IN THE UPPER ATMOSPHERE

In a paper to be communicated to the American Physical Society it is assumed that the ionization in the upper atmosphere is caused by the ultraviolet light of the Sun and that the ion- and electron-densities at noon at the equator are those required by the theory of wireless wave-propagation. From the laws of recombination of the ions and the diffusion and drift of the ions in the Earth's magnetic and gravitational fields, the distribution of the ions and electrons over the Earth is worked out. The distribution turns out to be that required by the diamagnetic theory of the solar diurnal-variation of the Earth's magnetism (Gunn, *Phys. Rev.*, v. 32, 1928 (133); *Terr. Mag.*, v. 34, 1929 (17)). The gravitational drift-currents are found to flow mainly along the parallels of latitude in the following way: On the daylight hemisphere (1) a current-sheet flowing eastward in the levels above 150 km, which at the sunrise and sunset longitudes divides into two sheets; (2) one of these flows westward on the day side of the Earth underneath (1) in the levels below 150 km, and (3) the other sheet continues eastward in the upper levels around on the night side of the Earth. The current is for the most part between the 40th

[4]Not yet published.

parallels of latitude, north and south, and falls to lower values at the higher latitudes. The total currents in the three sheets are about 10^7, 8×10^6, and 2×10^6 amperes, respectively. The east and west daytime current-sheets subtract from each other, leaving in effect an eastward current of about 2×10^6 amperes flowing around the Earth all the time. This causes a magnetic field agreeing in magnitude and type with that obtained by Bauer in his 1922 analysis of the magnetic field of the Earth of external origin. The drift-current system does not agree with that required by the atmospheric-current theory of the solar diurnal-variation of the Earth's magnetism (Chapman, *Proc. Roy. Soc. A*, v. 122, 1929 (369)).

As a result of the drift-currents, the sunset longitude of the Earth is at a potential of several hundred volts above that of the sunrise longitude. This electric field combined with the Earth's magnetic field causes the ions and electrons on the night side of the Earth to drift upward with velocities of order 10^2 cm sec^{-1}. The ions and electrons move into regions of lower pressure and therefore do not recombine as fast as they otherwise would. This removes a difficulty from an earlier calculation (Hulburt, *Phys. Rev.*, v. 31, 1928 (1018)) which yielded too great a night-time rate of disappearance of the free-charges. The upward drift at night of the ionization causes a rise of the Kennelly-Heaviside layer which is, partially at least, compensated by the fall due to the cooling and contraction of the atmosphere at night, and is complicated by the diffusion of the ions. It is difficult to say how much of the night-time rise of the layer observed in experiments with wireless rays may be genuine rise and how much may be an apparent rise due to delayed group velocities, or to other causes.

E. O. HULBURT

Naval Research Laboratory, Washington, D. C., July 14, 1929

SCALE-VALUES OF MAGNETIC VARIOMETERS[1]

F. P. Ulrich has made some further tests of the method of determination of scale-values by use of a large deflector as mentioned by McComb in the June 1928 number of the JOURNAL and described by Ludy in the March 1929 number. The values obtained with the horizontal-intensity variometer are in close agreement with those determined by the small deflector, and the use of the small deflector has been abandoned in connection with this instrument. Further tests are being conducted with the vertical-intensity variometer. The scale-values reduced to zero-ordinate as obtained with the small deflector at distances 25.8 and 27.2 cm and with the large deflector at 252.0 cm before and after each day's determinations with the small deflector during June 29 to July 15, 1929, are, respectively, as follows: June 29, 3.88,

[1]Communicated by permission of the Director, United States Coast and Geodetic Survey.

3.85, and 3.80, 3.82; July 8, 3.82, 3.83, and 3.90, 3.77; July 15, 3.78, 3.79, and 3.73, 3.86. Thus the mean values for the determinations on the three days with the small deflector are 3.83 and 3.82, respectively, for distances 25.8 and 27.2 cm, as against a mean value of 3.81 for the large deflector. It is to be noted that there was a mild magnetic storm on July 15.

H. E. McComb

U. S. Coast and Geodetic Survey, Washington, D. C., August 9, 1929

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory

January to March, 1929[1]

(*Latitude 57° 03′.0 N.; longitude, 135° 20′.1, or 9ʰ 01ᵐ.3 W. of Gr.*)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Ver. int.
1929	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Feb. 17	02	..	18	13	..	191.2	1329**	894**
Feb. 19	03	24	19	20	..	43.6	390	449
Feb. 26	19	23	28	16	..	91.8	1150*	744*
Mar. 11	13	56	13	13	..	193.3	1166*	895*
Mar. 15	09	..	16	14	..	113.4	1145	696*
Mar. 21	00	..	26	15	..	132.3	767	891**

*Curve went off paper in one direction. **Curve went off paper in both directions.

February 17-18, 1929—This storm began gradually, being active several hours before large fluctuations were recorded. From 10^h to 19^h on February 17 the curves show considerable motion but relatively slow so that the curves can be clearly followed at all times.

February 26-28, 1929—This storm had a very definite point of beginning. The storm was of magnetic character (1) for nearly a day before it shows the features of a (2) day. From 12^h to 21^h, February 27, and from 7^h to 15^h, February 28, considerable activity was recorded, particularly rapidly around 14^h February 28 for about one hour. The light was increased at 17^h February 27 so that the curves can be followed at all times.

March 11-13, 1929—This storm like the preceding one had a very sharp point of beginning and was of character (1) until March 12 at 3^h. From that time until 19^h March 12 the curves are very rapid and show large oscillations. From 5^h to 6^h and from 13^h to 16^h the motion was so rapid that the curves can not be definitely followed. This storm can be classified as a severe storm.

F. P. Ulrich, *Observer-in-Charge*

[1]Communicated by the Director, United States Coast and Geodetic Survey.

Cheltenham Magnetic Observatory

April to July, 1929[1]

(*Latitude 38° 44′.0 N.; longitude 76° 50′.5 or 5h 07m.4 W. of Gr.*)

There were no storms during April to June, 1929.

July 14-18, 1929—A magnetic disturbance began July 14 at 16h 30m but assumed no importance until from 1h to 2h July 15. There were bends in the curves giving ranges: Declination, 32′; horizontal intensity, 84γ; vertical intensity, 80γ. There were bends July 15 from 6h to 7h giving ranges: Declination 15′; horizontal intensity, 60γ; vertical intensity, 60γ. During the hour preceding midnight July 15 there were bends giving ranges: Declination, 20′; horizontal intensity, 80γ; vertical intensity, 80γ. On July 16 from 19h 30m to 20h 30m there was a change in horizontal intensity of 100γ, and vertical intensity rose to 60γ above normal. At other times the curves were slightly disturbed.

All times given are Greenwich civil mean time.

Geo. Hartnell, *Observer-in-Charge*

Huancayo Magnetic Observatory

March to April, 1929

(*Latitude 12° 02′.7 S.; longitude 75° 20′.4 or 5h 01m W. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Ver. int.
1929	*h m*	*d h m*	′	γ	γ
Mar. 11	13 53	13 05 ..	9.0	550	52

March 11, 1929—A severe magnetic storm began at 13h 53m on March 11 with a sharp decrease of 18γ in horizontal intensity and an immediate increase of 193γ the following four minutes. The declination and vertical-intensity traces also showed distinct increases within the next three or four minutes. The storm was distinguished by rapid but moderate fluctuations in horizontal intensity during the daily maxima of March 11 and 12, and by subnormal horizontal intensities with much slower changes during the rest of the time. Declination and vertical-intensity traces showed only moderate fluctuations during the storm, which ended at about 5h on March 13, at which time the horizontal-intensity trace became practically normal again.

All times given are Greenwich civil mean time.

Paul G. Ledig, *Observer-in-Charge*

[1]Communicated by the Director, United States Coast and Geodetic Survey.

Watheroo Magnetic Observatory

January to May, 1929

(Latitude 30° 19′.1 S.; longitude 115° 52′.6 or 7^h 44^m E. of Gr.)

Greenwich mean time					Range		
Beginning		Ending			Decl'n	Hor. int.	Ver. int.
1929	*h m*	*d*	*h*	*m*	′	γ	γ
Feb. 26	19 23	28	18	..	21.6	187	155
Mar. 11	13 54	13	15	58	30.3	247	187

February 26-28, 1929—This mild but protracted magnetic disturbance began at 19^h 23^m. It was ushered in by a sudden commencement which, though not large, was simultaneous for all three elements. The first period of the storm covered an interval of approximately twelve hours, during which the oscillations were small though particularly rapid in the case of declination. During this time the departures from the normal curves were not large. The first period ended with a sharp displacement of the horizontal-intensity curve at $7^h.7$ February 27. The second period of the disturbance lasted four hours and there were only slight disturbances of the traces. It was followed by a third, during which the oscillations were large. From 20^h February 27 to 4^h February 28 rapid short-amplitude waves were superimposed on the larger oscillations in the case of all three elements. There followed a period of comparative quiescence till 12^h February 28. For the three hours immediately afterward there was a short-lived recrudescence of the storm. During this time the horizontal intensity changed 80γ in approximately twelve minutes. This was the most sustained and rapid oscillation of the storm. The storm had completely disappeared by 18^h on February 28.

March 11-13, 1929—A moderate though rather protracted storm commenced suddenly at 13^h 54^m G. M. T. on March 11, there being a rapid increase of 70γ in horizontal intensity and smaller decreases in vertical intensity and declination, preceded, however, by a slight oscillation in the opposite direction in all three elements. For the thirteen hours immediately following the commencement, the traces showed no marked departure from the mean curve, though characterized by rapid fluctuations of small amplitude. From 3^h to 20^h on March 12 all three elements underwent large and sometimes rapid changes, those occurring till 11^h being of small period, while from 11^h to 20^h larger and slower variations were exhibited. Subsequent to 20^h March 12 the elements were only moderately displaced and subject to small rapid fluctuations, more particularly in horizontal intensity, which did not recover its normal value till 16^h March 13, when the storm ended.

All times given are Greenwich civil mean time.

H. F. Johnston, *Observer-in-Charge*

REVIEWS AND ABSTRACTS

(See also page 223)

CHREE, C.: *Magnetic disturbance and its relation to aurora.* Australasian Antarctic Expedition, 1911-14, under the leadership of Sir Douglas Mawson. Scientific reports, Ser. B, v. 2, Part 2. Sydney, 1929 (195-331). 30 cm.

Magnetic disturbances—Discussing the magnetic disturbances at Cape Denison in the years 1912 and 1913, Dr. Chree has made use of a number of different criteria for the disturbances, namely, the magnetic character-number which is assigned to a day or an hour according to the general appearance of the curve, the absolute daily ranges, the mean of the hourly ranges or the hourly ranges alone in case the distribution of the disturbances on the hours of the day is to be investigated, the squares of the absolute daily ranges or the sum of the squares of the hourly ranges. He finds none of these criteria to have special advantages and concludes that "Until disturbance has been defined in such a way that an exact numerical measure is forthcoming, we cannot pass a final judgment as to what is the best criterion."

Comparisons are made between the simultaneous observations at Cape Denison, Cape Evans, and Eskdalemuir. Cape Denison is found to be a more disturbed station than Cape Evans, the disturbances being both more frequent and more violent at the former station. From the comparisons between the records at Cape Denison and Eskdalemuir the conclusion is drawn that the disturbances have a pronounced annual period in the antarctic, the summer being the time of maximum. This result is verified by other compilations. The year 1912 proved to be much more disturbed in the antarctic than the year 1913, though no corresponding decrease in the disturbances was observed in temperate latitudes. The 27-day period appeared at least as pronounced in the antarctic as in temperate latitudes. The international disturbed and quiet days were found to be thoroughly representative also in the antarctic.

The diurnal period of the disturbances showed at Cape Denison a double oscillation. The principal maximum of the disturbances occurred at 1-2^h G. M. T., the secondary at 14^h, corresponding to 11^h, and 23-24^h L. M. T., respectively. A comparison between Cape Evans and Cape Denison reveals that the maximum occurs about four hours later at the latter station, the difference in the time of occurrence exceeding the difference in local time (about 1.5 hours) and at both stations the time of occurrence appears to be independent of the season of the year. Comparisons between Cape Evans and Eskdalemuir had previously shown that the time of maximum practically coincided at these two stations when referred to G. M. T., in spite of the great difference in longitude. On account of this coincidence Dr. Chree had suggested the possibility that disturbances over the whole earth might follow universal time, but now he points out that such a conception cannot be upheld.

Magnetic disturbances and aurora—On the basis of the notes regarding aurora, auroral characters 0, 0.5, 1.0, 1.5, and 2.0 were assigned to each observation and each hour was given an auroral character-number which was regarded as defined by the highest number assigned to any single observation in the 60 minutes (G. M. T.).

A comparison between the auroral character and the magnetic character of the single hours showed that auroral characters 0 and 0.5 in most cases were

associated with magnetic character 0 or 1 while auroral character 1.5 or 2 in most cases had been assigned to hours with magnetic character 1 or 2, though several striking exceptions occurred.

It was difficult to arrive at definite conclusions regarding a possible relation between the aurora and the magnetic disturbances because aurora could be observed in the night hours only while the greatest magnetic disturbances occurred shortly before noon, when daylight prevented the observation of possibly present aurora. The period in the occurrence of the aurora during the night showed a maximum at about 11^h L. M. T., corresponding to the secondary maximum in the magnetic disturbances. The aurora frequence showed a mini mum at 2^h and thereafter an increase up to the time when daylight intervened. The magnetic disturbances also show a minimum at 2^h L. M. T., and thereafter an increase until the primary maximum, ending at $11^h\ 30^m$ L. M. T. Whether or not the aurora increased to a corresponding maximum is unknown.

In view of these facts it is surprising that Chree in one place remarks that "Everything considered, it seems most reasonable to suppose that the presence or absence of aurora makes no fundamental difference to magnetic disturbance." It must be admitted that the compilations and the careful discussion of the single cases fail to disclose any remarkable coincidence between aurora and magnetic disturbances but a relation between the two phenomena undoubtedly exists.

The writer found when discussing the observations from the *Maud* Expedition[1] that an aurora appearing at a small elevation above the horizon as a rule was accompanied by a smaller magnetic disturbance than a high aurora and that the quiet forms were accompanied by weaker disturbances than the moving forms. These results were derived from observations at a station in latitude 70° 43′ north and longitude 165° 25′ east and were based on registrations of the declination only. It is of interest to state that these rules are also found from the observations at Cape Denison. From the data in Table LXXII in Chree's paper I find

Angle of elevation of aurora	Form	Mean ranges in *D*	*H*	*Z*
0° to 30°	Arcs, bands	27γ	24γ	28γ
	Curtains, streamers	51	38	40
30° to 90°	Arcs, bands	53	35	74
	Curtains, streamers	59	92	79

In this connection I may draw attention to the opinion which has been expressed by O Krogness,[2] namely that the rapid variations, which are observed during perturbations, mainly are caused by earth-currents which are induced by the current-systems in the upper part or outside of the atmosphere, which also manifest themselves as rapidly changing forms of aurora. In order to arrive at more definite conclusions it seems indispensable to study the single magnetic storms as begun by Kr. Birkeland and his collaborators.

H. U. Sverdrup

[1] H. U. Sverdrup, Magnetic, atmospheric-electric, and auroral results, *Maud* Expedition, 1918-1925. Washington, D. C., Carnegie Inst., Pub. No. 175, v. 6, 1927.

[2] O. Krogness, Short report of various researches regarding aurora borealis and allied phenomena. Tromsö, 1928.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Apia Observatory. Report for 1926. Published by the direction of the Honorary Board of Advice, Wellington, N. Z. Wellingon, W. A. G. Skinner, Govt. Printer, 1929 (96). 25 cm.

Bangkok, Royal Survey Department. Report on the operations of the Royal Survey Department, Ministry of War, for the year 1926-27. Bangkok, Bangkok Times Press, Ltd., 1929 (73 with maps and illus.). 34 cm. [Contains results of magnetic observations 1905-1927.]

Bartels, J. Die radiale Begrenzung des Magnetfeldes der Sonne. Naturw., Berlin, Jahrg. 17, Heft 15, 1929 (243-244).

Berlin, Preussisches Meteorologisches Institut. Bericht über die Tätigkeit des Preussischen Meteorologischen Instituts im Jahre 1928. Mit einem Anhang, enthaltend wissenschaftliche Mitteilungen. Berlin, Veröff. met. Inst., Nr. 362, 1929 (131). 25 cm. [Contains report on magnetic work, pp. 32-37.]

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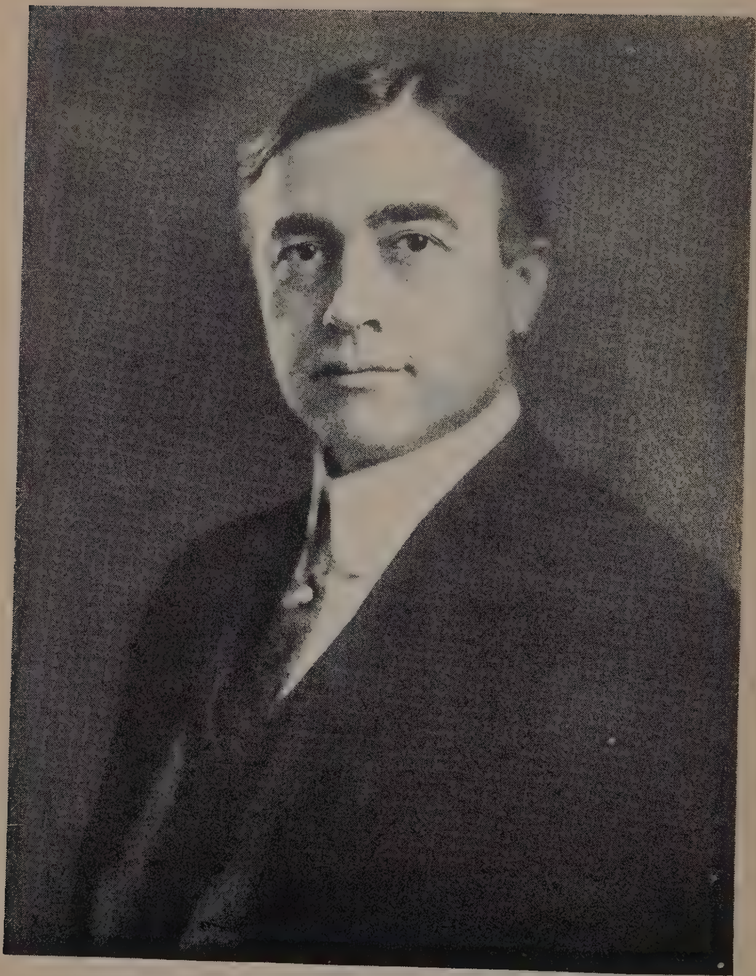
Plate II



Sincerely yours,
J. P. Ault

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 34 DECEMBER, 1929 No. 4

JAMES PERCY AULT, 1881–1929[1]

BY H. D. HARRADON

The Department of Terrestrial Magnetism of the Carnegie Institution of Washington has suffered an irreparable loss in the untimely death of Captain J. P. Ault, chief of its Section of Ocean Work and Commander of the non-magnetic ship *Carnegie*. On November 29, 1929, while a supply of gasoline was being taken on board in the harbor of Apia, Western Samoa, an explosion took place as a result of which Captain Ault lost his life, and the vessel, together with all its instrumental equipment, was destroyed. Thus the extensive program of the seventh cruise of the *Carnegie*, which up to that time, under the able direction of Captain Ault, had yielded most valuable contributions to our knowledge of the oceans, was brought to an abrupt termination.

Captain Ault was born on October 29, 1881, at Olathe, Kansas, and educated at Baker University where he received an A.B. degree in 1904. Even while studying in the University he took an active interest in the work of the then newly established magnetic observatory of the United States Coast and Geodetic Survey at Baldwin, Kansas, where he served as observatory assistant from January 1901 to June 1904. In the latter month he was appointed as magnetic observer in the Department of Terrestrial Magnetism and the next year, after receiving the necessary preliminary training on the U. S. Coast Survey vessel *Bache* on a cruise from Baltimore to Panama, he was assigned to scientific work on the magnetic-survey vessel *Galilee* where he remained until November 1906. During the next two years he was engaged at the office of the Department in Washington and on magnetic field work in Mexico and Canada, carrying out in the latter country a difficult explora-

[1]The portrait of Capt. Ault, from which the frontispiece was made, was kindly supplied by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

tory trip in the course of which he secured magnetic results in territory where none had previously been obtained. In order to fit himself more thoroughly for a scientific career he next pursued postgraduate studies at Columbia University from which institution he received an A.M. degree in 1909. In view of his skill and experience gained on earlier expeditions, he was again, in 1912, placed in charge of field parties in Peru, Bolivia, and Chile, for the purpose of training new observers in making magnetic determinations under field conditions. In the course of the ever-broadening scope of the Department's activities, special investigations were early instituted for determining possible variations in the Earth's magnetic and electric fields due to a total solar eclipse, and in the case of the solar eclipse of September 10, 1923, at Point Loma, California, and that of January 24, 1925, at Greenport, Long Island, it was Captain Ault who was selected to assume the responsibility of directing these delicate measurements.

In the general plan of a magnetic survey of the Globe which constituted one of the major operations of the Department, the ocean work of the non-magnetic ship *Carnegie* was destined to play an important part. For the successful execution of this ambitious undertaking, Captain Ault, first as a member of the scientific staff under its first commander William J. Peters, and later as commander of the vessel, has been largely responsible, participating in all but two of the seven cruises and being in command, except for a brief period, since June 1, 1914. In the course of these voyages, the average length of which approximates 300,000 nautical miles, the *Carnegie* sailed all the oceans, was exposed to the heat and pestilence of tropical seas and ports, and battled with arctic and antarctic storms. Particularly hazardous was the voyage encircling the South Pole in subantarctic latitudes during the period from December 5, 1915, to April 1, 1916. Since Captain Ault took command of the vessel, the scientific work steadily expanded until on the seventh cruise it embraced a comprehensive program of oceanographical and meteorological researches in addition to the original schedule of observations in terrestrial magnetism and atmospheric electricity.

Captain Ault's services to science received merited recognition. He was a member of the American Geophysical Union (chairman of the Section of Oceanography, 1922-1924), American Physical Society, American Association for the Advancement of Science, Philosophical Society of Washington (of which he was secretary,

1923-1924, vice-president, 1925-1926, and president, 1927), Washington Society of Engineers, Advisory Committee of Maury U. S. Naval Oceanographical Research, American Geographical Society, and National Geographic Society. On May 18, 1927, he was appointed a lieutenant-commander in the United States Volunteer Naval Reserve.

As a popular lecturer Captain Ault enjoyed a wide reputation, being frequently called upon to deliver addresses before various societies and organizations. His lectures were always interspersed with original anecdotes and enlivened by characteristic bits of humor which added greatly to the interest of his hearers.

He was a man of exalted ideals and sterling character. Gifted to an unusual degree with the rare qualities which make for leadership, he was able, under the most trying circumstances on the long cruises of the *Carnegie* to maintain discipline and to preserve the harmonious cooperation of the men. To a charming personality was added a spirit of sympathetic congeniality which won for him the highest esteem and enduring friendship of all whose privilege it was to work with him. By those, however, who are engaged in the study of geophysical problems he will always be remembered as one who did much to advance our knowledge of that science to the service of which he gave his life.

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Preliminary results of ocean magnetic observations on the *Carnegie* from Honolulu to Pago Pago, April-June, 1921. Terr. Mag., v. 26, 1921 (91-95).

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DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON,
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IN APPRECIATION OF THE WORK OF JAMES PERCY AULT OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM

By Fred E. Wright

Disaster on the sea rarely strikes singly. The explosion that destroyed the ship *Carnegie* on November 29, 1929, in Apia, took also the life of its commander, Captain James Percy Ault, under whose direction all scientific work was being done and to whose initiative and enthusiasm the success of the expedition was primarily due.

The cruise that ended so tragically was the seventh cruise of the *Carnegie*. During the past twenty years it covered more than than three hundred thousand miles; the results obtained on its cruises over the seven seas are the most important contributions that have been made to terrestrial magnetism and electricty. The ship was a floating laboratory and was thoroughly equipped for geophysical work at sea; its records are, in many respects, of pioneer character, establishing new methods of approach.

In all these developments and actual accomplishments Captain Ault had a leading part. Intensely interested as he was in geophysics, the work done by him and under his direction on the *Carnegie* during four of her cruises is a monument to his ability. To keep both crew and scientific staff contented and occupied for long periods on a ship at sea is evidence of real leadership; this was the outstanding factor that made for the success attained. Of high ideals and sterling character, and of a genial, lovable personality, Captain Ault was held in high regard by his associates. His devotion to his work and his loyalty to the Carnegie Institution set an inspiring example of unselfishness that had a wide influence. We mourn the loss of a good friend and an able investigator. His service to geophysics will be a lasting memorial.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.

IN TRIBUTE TO THE MEMORY OF JAMES PERCY AULT

By H. W. Fisk

Throughout the record of achievement of the *Carnegie* on all oceans runs the reflected personality of the man who has been associated with her from the beginning, and who, for the past fifteen years, has been her commander.

His service under his predecessor, first on the *Galilee*, then on the early cruises of the *Carnegie*, prepared him for the responsibility,

but Nature gave him the qualities of heart and mind essential to successful leadership.

Ready in making decision in the face of the unexpected, forcible in the exercise of authority, his assurance commanded confidence and obtained willing compliance in the presence of the hazards of the sea. Yet he had, and abundantly, that genial comradeship and that sympathetic readiness to add to his responsibilities a share of the burdens and physical hardships of a rigorous routine which constrained his associates to banish petty personal grievance and to labor together in achieving a common purpose.

To him every problem was a challenge and every opportunity was a potential victory. His enthusiasm and energetic example inspired his coworkers to surmount obstacles, overcome difficulties, and give unselfish devotion to their work. Though untimely interrupted, his service in the great field of research in oceanography has but begun for his achievements endure as beacons to guide those who follow.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D. C.

Scientific Staff, Ship *Carnegie*, November 1929
FORBUSH, SEATON, SCOTT, GRAHAM, PAUL
PARKINSON, AULT, SOULE

THE EFFECT OF CONDENSATION-NUCLEI IN ATMOSPHERIC-ELECTRIC OBSERVATIONS[1]

By Geoffrey Builder

Abstract—Curves are given, based on observations made at the Watheroo Magnetic Observatory, showing the relations found between the counts of condensation-nuclei made with an Aitken counter and the simultaneous values of the atmospheric conductivity and potential-gradient. There is some disagreement with the data given by Wait, based on fewer observations. It is concluded that, for the range of observation, there is an approximately linear relation between the nuclei-count and the reciprocals of the polar conductivities and between the nuclei-count and the atmospheric potential-gradient. Owing particularly to the influence of the distribution of the pollution with respect to height the potential-gradient curves are not very definite. The effect of the pollution on the conductivity is expressed in terms of the linear recombination-law of Schweidler and the extension of this to explain the effect of high values of humidity is noted. An approximate and non-linear extrapolation of the curve for reciprocals of negative conductivity against nuclei-count is given based on Schweidler's equation of recombination in the presence of Langevin ions and uncharged nuclei.

The effect of atmospheric pollution in determining the values of the atmospheric-electric elements has been frequently discussed. Chree and Watson[2] investigated the relation between pollution and atmospheric potential-gradient, using the Owen method of determining the amount of pollution present, and found that the potential gradient is greater in times of greater pollution. Wait[3], using an Aitken nuclei-counter has given curves showing the relation between the number of condensation-nuclei and the values of both atmospheric conductivity and potential gradient. The following brief investigation of the effect was undertaken because it did not appear that Wait's preliminary results represent satisfactorily the *magnitude* of the effect for great amounts of pollution. The normal mean values of the potential gradient and the total conductivity at the Watheroo Magnetic Observatory, Western Australia, are of the order of 80 volts per meter and 30×10^{-5} E. S. U., respectively. However, during the summer months there is a wide range in the amount of impurity in the air owing to the prevalence of bush-fires and cases are not infrequently noted when the potential gradient increases to 300 volts or more and the total conductivity reaches values as low as 2×10^{-5} E. S. U. Values of this order are often maintained for some hours and there seems little doubt that the abnormal values are due solely to pollution present. Extrapolation of Wait's curves would indicate only an increase to 120 volts per meter for the potential gradient and a decrease to about 8×10^{-5} E. S. U. for the conductivity under conditions which must be regarded as extreme for Watheroo—about 50,000 nuclei per cc.

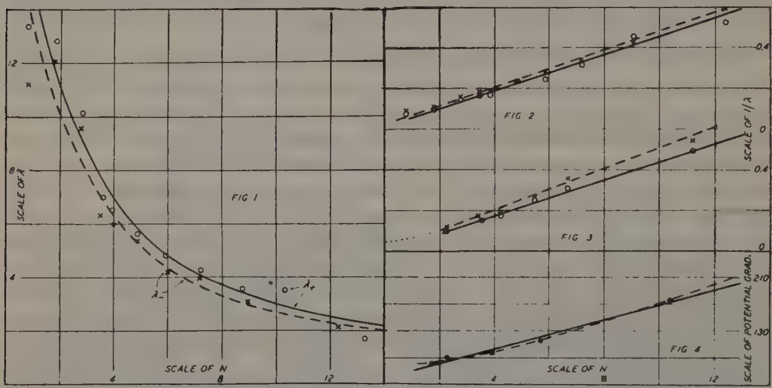
A series of observations was therefore taken during January, February, and March of 1928 at the Watheroo Observatory. An

[1]Based on communication presented for the author by H. F. Johnston at the Second Conference of Physicists, Mathematicians, and Astronomers in August 1929 at Melbourne.

[2]*Proc. R. Soc.*, A, v. 105, 1924 (311-333).

[3]*Terr. Mag.*, v. 32, 1927 (31-35).

Aitken pocket-counter was used and the Observatory electrograms gave the simultaneous value of the atmospheric elements.[4] Meteorological conditions at the times of observation were also noted. Considering the short period over which the data were collected and the fairly regular spacing of the observations from day to day and on each day, no attempt has been made to correct for diurnal or other variation of the atmospheric-electric elements. The nuclei-counts obtained range from a few hundred to about 20,000 per cc, though few data were obtained at either extreme of this range. The results are summarised in the diagrams, the following abbreviations being used: N, nuclei-count in thousands per cc; λ_+, positive conductivity in E. S. U. $\times 10^{-5}$; λ_-, negative conductivity in E. S. U. $\times 10^{-5}$; PG, potential gradient in volts per meter.



Figs. 1 to 4—Curves showing the relations found between nuclei-counts and atmospheric conductivity and potential-gradient (N=nuclei-count in thousands per cc; λ_+=positive conductivity and λ_-= negative conductivity in E. S. U.$\times 10^{-5}$; P. G.=in volts per meter)

The curves of Figure 1 show the relation found between the nuclei-count and the positive and negative conductivities, each plotted point representing the mean of 20 observations. This method of meaning the observations is unsatisfactory when the curve deviates so much from linearity. The reciprocals of the conductivities which have been plotted against the nuclei-count in Figures 2 and 3 give the corresponding curves for 80 selected observations for which the relative humidity was between 17 and 28 per cent.

The agreement between these sets of curves indicates a general independence of the particular selection of data which has been noticeable throughout the results given. It is concluded that for the range of nuclei-count observed there is an approximately

[4]The recording instruments of the Observatory are standard observatory-types designed and constructed by the Department of Terrestrial Magnetism. That for conductivity is after Gerdien's design with scale-value for electrograms of approximately 10^{-6} E. S. U. per mm for both positive and negative conductivity and that for potential gradient using an ionium-collector with scale-value of about 4 volts per mm with reduction-factor of 1.07 to reduce to volts per meter.

linear relation between the nuclei-count and the reciprocals of the polar conductivities. It may be noted that the mean straight lines which have been drawn pass very close to the origin when extrapolated. This result accords well with the linear recombination-law of Schweidler. The magnitude of the effect is such that decrease of ionic mobility due to the atmospheric pollution is not a possible explanation.

Schweidler[5] has shown, from very general considerations, that the recombination of large and small ions and the capture of small ions by uncharged nuclei may be expressed by the equation

$$q - an^2 - ynN = \mathrm{d}n/\mathrm{d}t = 0$$

for the equilibrium-condition, where N is the number of uncharged nuclei and Langevin ions, y is a constant, and the other symbols have the usual significance. If the quantity $(an + yN)$ is replaced by β' this becomes

$$q = \beta' n$$

Schweidler has called the quantity β' the diminution-constant. If, further, the diminution-constant is assumed large compared with the quantity an this becomes approximately

$$q = ynN$$

the specified condition being satisfied for quite small amounts of pollution. This is the type of relation found between the reciprocals of the conductivities and the nuclei-count and the agreement is particularly good for the curves of Figure 3 in which any effect of humidity has been practically eliminated. If we consider n as a measure of the conductivity and N as being given by the counts made by the Aitken counter, the value of the quantity y/q may be determined from these curves. For example, for the negative conductivity this gives $y/q = 56 \times 10^{-8}$ for an assumed value of the mobility of the negative ion of one cm per sec per volt per cm. Unfortunately no data are available for the value of q for the location. If, however, some such value as 14 be assumed for q a corresponding value of y may be obtained and all the quantities of the equation $q - an^2 - ynN = 0$ are then approximately known. The curves for nuclei-count and reciprocal conductivity may then be extrapolated to zero nuclei-count by this relation. This has been done for negative conductivity and the extrapolation is shown by the dotted line of Figure 3. The value of the conductivity for zero nuclei-count so obtained is of the order of 30×10^{-5} E. S. U., practically the same as by Wait's curve. Considering the number of assumptions made, this is in good agreement with values of this order observed on unusually clear mornings, and the seemingly low value of conductivity observed for the first point on the conductivity curves 2 accords well with the extrapolation. The values

[5] *Phil. Mag.*, v. 44, 1897; Wien, *SitzBer. Ak. Wiss.*, v. 133, 1924 (23-27).

of the diminution-constant under various conditions of pollution are in sufficiently good agreement with the observed values given by Schweidler[5], Schlenck[6], and Nolan, Boylan and de Sachy[7].

The curves do not indicate any marked change in the ratio of positive to negative conductivity for increasing amount of pollution.

The potential-gradient observations are in general conformity with the curve of Figure 4, in which each plotted point represents the mean of 40 observations. From the data it appears to be probable that the relationship of potential gradient to nuclei-count is a linear one though the data are not sufficient to draw definite conclusions and the broken-line curve of Figure 4 is also a permissible interpretation of the results, but the data are certainly sufficient to show that much larger increases of potential gradient may be expected for greater amounts of pollution than has actually been recorded in these observations.

A large amount of data would be necessary to obtain a definite relation between the potential gradient and nuclei-count and, even if obtained, the interpretation of the relationship would be very difficult. Apart from the marked effect of the meteorological conditions on the values of the potential gradient, it is very probable that the distribution of the pollution with respect to height will play an important part in determining the value of the gradient[8] and the case is much more complicated than that of the conductivity where it is reasonable to assume that the effect of the pollution is determinable in terms of the pollution at the recording apparatus. There is little doubt that, where the pollution extends to considerable heights, the potential gradient is much lower than might be expected from a determination of the polution near the collector and from the mean curve given. To take an example which has been noted on a number of occasions: Smoke from a distant fire giving a nuclei-count of the same order as that from a small local fire may have very little effect on the potential gradient when compared with the effect of the smaller fire, though the effects on the conductivity may be much the same in the two cases. It is not unlikely that these and similar cases may be explained in terms of the effects on the vertical atmospheric current.

While it is admitted that the number of observations used, about 200, is insufficient to carry any great weight, the data obtained are more extensive than those secured by Wait and the results appear to be in better agreement with the observed effects. The quantitative aspect of the disagreement with Wait's work is clear from the curves given. Furthermore, Wait calls attention to the fact that "the particular shapes of the curves are interesting in that the variations are rapid for low nuclei-count and tend to become constant for high nuclei-count." From the data given in this paper it

[6]Wien, *Sitz Ber. Ak. Wiss.*, v. 133, 1924 (29-33).

[7]See "The electrical conductivity of the atmosphere," by Victor Hess, for these and footnotes 5 and 6 above.

[8]Chree and Watson, *loc. cit.*

does not seem that this is true of potential gradient and this does not appear to be an adequate expression of the variation of the conductivity with nuclei-count. While it is true that the conductivity decreases more slowly with nuclei-count for high nuclei-counts, according to the curves found by both Wait and the author, it has been shown above that the *effect* of the pollution can be expressed in terms of a linear recombination-law.*

This investigation has not been carried further because it does not seem that the accumulation of such data can have great value without simultaneous determination of such quantities as the coefficient of dimunition and the ionization. If the effect of the dust is to increase the rate of recombination of the ions by absorption, with the temporary formation of Langevin ions, it is obvious that the quantity which it is important to determine in its relation to atmospheric electricity is the coefficient of diminution. The dependence of this coefficient on the pollution of the air can only be determined satisfactorily in the laboratory where such factors as the size of the particles and their chemical composition are under control. Also, nuclei-count observations must necessarily be at a disadvantage whenever an attempt is made to compare the data obtained in different parts of the whole world, since the main sources of pollution may vary widely from place to place.

An attempt was also made to determine the relationship between the recorded values of conductivity and the values of the relative humidity. For this purpose the values of relative humidity noted at the time of nuclei-count observations were used and also the values observed at 9 a. m. each day during the winter months of 1927 and 1928. No definite correlation could be established except for one point which is worthy of note. There is usually a marked decrease of conductivity and increase of potential gradient in times of fog or mist and generally at times when the visibility is low. It is supposed that this is due to a further increase in the coefficient of diminution owing to the absorption of water-vapour on the condensation-nuclei increasing the effectiveness of the nuclei in the capture of ions. This effect has been frequently remarked by Chree[9] and others. An examination of curves 2 and

*Since the preparation of this paper an article by Nolan and O'Brolchain (*Proc. R. Irish Acad.*, A, v. 38, 1929) has been received, giving the results of a survey of available data on nuclei-count and conductivity or ionic content showing apparently that the recombination-law requires some modification. Taking from Figure 1 of the present paper the values of N and of n (using $v=$ one cm per second per volt per cm) and using $\alpha=1.6\times10^{-6}$, $\gamma=1.0\times10^{-4}$, and $\zeta=55\times10^{-5}$, values of q were calculated by O. W. Torreson from the two formulæ as follows:

n	N	Calculated values of q: Linear form	Calculated values of q: Square-root form
140	14,000	15.6	9.2
189	10,000	19.0	10.5
231	8,000	18.6	11.4
308	6,000	18.6	13.3
448	4,000	18.2	15.9
560	3,000	17.3	17.4
700	2,000	14.8	17.9
826	1,333	12.1	17.7
910	1,000	10.4	17.1

This comparison affords little evidence as to which law is most nearly correct.—*Ed.*

[9] *Nature*, v. 77, Feb. 13, 1908 (343).

3 shows that lower values of humidity also have an effect. The mean value of relative humidity for the data of Figure 2 is 40 per cent while that for Figure 3 is 20 per cent.

In conclusion the author wishes to thank the Commonwealth Bureau of Meteorology for the loan of the Aitken pocket-counter used.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Watheroo, Western Australia, July 20, 1929.

REVIEWS AND ABSTRACTS

(See also pages 300 and 325)

Radcliffe, J. A. *The physical principles of wireless.* With a foreword by E. V. Appleton. New York, E. P. Dutton and Co., Inc., 1929 (viii+104 with 37 diagrams). 17 cm.

As stated in the foreword, this book is addressed primarily to physicists and to engineers having some knowledge of the fundamentals of electricity without knowing the special application of these fundamentals to wireless. The author is remarkably successful in giving a very complete explanation of the physical principles involved in a surprisingly concise form.

The book is divided into chapters on oscillatory circuits, valves, transmitters, receivers, telephony, amplifiers, and one on miscellaneous subjects. In each chapter the author defines, and in a few paragraphs explains, the meaning and use of terms which are peculiar to the subject, and yet are essential to an understanding of it. In regard to valves for instance, the underlying principle of thermal emission is well known. To understand the uses of valves, however, it is also necessary to know their characteristics, amplification-factor, mutual conductance, the conditions of oscillation, the effect of high- or low-plate resistance, etc. Such terms the author explains in a way which is at once complete, concise, and readable. In this lies the value of the book to those for whom time limitations will not permit a study of more involved texts.

In the last chapter, the author calls attention to some of the problems which are at present of greatest interest to investigators, such as the production and measurement of high frequencies, the effect of the Kennelly-Heaviside layer on the propagation of waves, echo-studies, and directional effects. This chapter particularly shows the position of wireless in the science of physics.

L. R. Hafstad

RELIMINARY RESULTS OF OCEAN MAGNETIC OBSERVATIONS ON THE *CARNEGIE* FROM JAPAN TO CALIFORNIA TO HAWAII, JUNE TO SEPTEMBER, 1929[1]

By J. P. Ault, *Commanding the Carnegie*

ABLE 1—*Preliminary Magnetic Results on Cruise VII of Carnegie, Pacific Ocean June to September, 1929*
bservers[2]: J. P. Ault, O. W. Torreson, F. M. Soule, S. E. Forbush, W. E. Scott, L. A. Jones, S. L. Seaton, and A. Erickson)

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1929	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
n 25[c]	34 47 N	140 46	5.1W	......	......	+0.1	+0.3	0.0	.....	.....	.....	.....	.....	.....
25	35 02 N	141 16	5.0W	......	......	+0.2	+0.3	0.0	.....	.....	.....	.....	.....	.....
26	35 51 N	141 49	......	48.9 N	.297	.....	.....	.....	+0.8	+0.1	+0.7	+4	0	+5
26	36 11 N	142 33	5.4W	......	......	−0.1	0.0	−0.2	.....	.....	.....	.....	.....	.....
27	36 34 N	143 27	5.2W	......	......	0.0	+0.3	0.0	.....	.....	.....	.....	.....	.....
27	36 39 N	143 58	5.0W	......	......	+0.2	+0.3	+0.1	.....	.....	.....	.....	.....	.....
28	36 42 N	145 08	4.9W	......	......	+0.1	+0.4	0.0	.....	.....	.....	.....	.....	.....
28	36 44 N	145 26	......	49.5 N	.291	.....	.....	.....	+0.6	+0.4	+0.4	+3	+1	+5
29	38 04 N	145 34	5.3W	......	......	0.0	+0.3	−0.1	.....	.....	.....	.....	.....	.....
30	38 05 N	146 34	4.8W	......	......	+0.3	+0.6	+0.2	.....	.....	.....	.....	.....	.....
30	38 06 N	146 53	......	50.8 N	.285	.....	.....	.....	+0.3	−0.1	+0.2	+3	+1	+4
30	38 20 N	147 18	4.8W	......	......	+0.1	+0.5	−0.1	.....	.....	.....	.....	.....	.....
ıl 1	39 05 N	148 02	5.5W	......	......	−0.6	−0.2	−0.6	.....	.....	.....	.....	.....	.....
2	39 36 N	149 09	4.6W	......	......	−0.1	+0.4	−0.1	.....	.....	.....	.....	.....	.....
2	39 42 N	149 17	......	52.4 N	.278	.....	.....	.....	+0.4	+0.2	+0.4	+2	0	+2
2	40 02 N	149 56	5.1W	......	......	−0.6	−0.2	−0.7	.....	.....	.....	.....	.....	.....
3	40 28 N	151 32	4.5W	......	......	−0.4	0.0	−0.4	.....	.....	.....	.....	.....	.....
4	41 27 N	153 34	......	53.6 N	.270	.....	.....	.....	−0.3	0.0	+0.2	+3	+1	+4
5	42 23 N	155 18	2.7W	......	......	+0.4	+0.8	+0.3	.....	.....	.....	.....	.....	.....
6	43 32 N	158 03	......	55.4 N	.259	.....	.....	.....	−0.4	0.0	0.0	+2	−1	+2
8	46 44 N	162 20	1.0W	......	......	+0.3	+0.6	−0.1	.....	.....	.....	.....	.....	.....
8	46 51 N	162 40	......	58.6 N	.245	.....	.....	.....	+0.2	+0.1	+0.5	0	−3	−1
9	47 03 N	166 18	0.9 E	......	......	+0.2	+0.4	−0.1	.....	.....	.....	.....	.....	.....
10	46 53 N	169 01	3.2 E	......	......	+1.2	+1.5	+0.8	.....	.....	.....	.....	.....	.....
10	46 48 N	169 13	......	58.4 N	.245	.....	.....	.....	0.0	—0.3	+0.3	+3	+3	+2
11	46 06 N	171 30	3.6 E	......	......	+0.4	+0.6	0.0	.....	.....	.....	.....	.....	.....
11	45 47 N	171 59	3.0 E	......	......	−0.6	−0.3	−0.9	.....	.....	.....	.....	.....	.....
12	45 11 N	172 53	......	57.2 N	.245	.....	.....	.....	−0.1	+0.1	+0.2	0	0	−2
14	47 56 N	177 44	......	59.9 N	.234	.....	.....	.....	+0.1	+0.1	+0.2	0	−1	−2
14[d]	49 03 N	182 46	......	61.3 N	.228	.....	.....	.....	0.0	0.0	+0.3	0	0	−2
14[d]	49 25 N	183 57	9.9 E	......	......	−0.1	+0.5	0.0	.....	.....	.....	.....	.....	.....
15	50 18 N	186 44	12.6 E	......	......	+1.3	+1.4	+1.2	.....	.....	.....	.....	.....	.....
15	50 40 N	188 15	11.7 E	......	......	−0.4	−0.3	−0.5	.....	.....	.....	.....	.....	.....
16	51 07 N	191 46	14.2 E	......	......	+0.2	+0.6	+0.3	.....	.....	.....	.....	.....	.....
16	51 15 N	192 11	......	63.9 N	.218	.....	.....	.....	−0.3	−0.4	−0.1	+3	+2	+2
17	52 29 N	199 08	17.8 E	......	......	+0.3	0.0	−0.1	.....	.....	.....	.....	.....	.....
18	52 40 N	203 29	20.8 E	......	......	+1.3	+1.1	+1.3	.....	.....	.....	.....	.....	.....
18	52 38 N	204 00	......	67.1 N	.201	.....	.....	.....	+0.1	−0.1	+0.2	−1	0	−1

[a]Charts used for comparison: U. S. Hydrographic Office charts 1700, 1701, and 2406 for 1925; British Admiralty charts 776 and 3777 for 1927, 3598 and 3603 for 1922; Reichs-Marine-Amt. charts Tit. XIV, 2, 2a, and 2b for 1920. All chart-alues have been corrected to 1929.5 for observations of June 25 to July 27 and to 1929.7 for those of September 5 to 23, on ccount of secular-change rate indicated by the respective charts. The chart-differences are obtained by subtracting the hart-values from those determined on the *Carnegie*, east declination, north inclination, and horizontal intensity being ckoned as positive and west declination and south inclination as negative.

[b]Expressed in units of third decimal C. G. S.

[c]The *Carnegie* was at Yokohama, Japan, during June 7 to 24, 1929.

[d]July 14 repeated on account of crossing the 180th meridian.

[1]For previous values obtained on Cruise VII, see *Terr. Mag.*, v. 33, pp. 121-128, 189-194, and v. 34, pp. 23-31, 117-21, 249-256.

[2]S. E. Forbush and S. L. Seaton took the places beginning in September on the observing staff previously held by O. V. Torreson and L. A. Jones, respectively; A. Erickson replaced J. H. Paul in the magnetic observations beginning in June, he latter's time being all taken after that by the chemical and biological program and other duties.

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	I	H	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U.
1929	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
Jul 18	52 27 N	205 17	20.8 E	...	...	+0.5	+0.4	+0.7	...	...	...	...	...	...
20	50 27 N	213 30	23.9 E	...	...	+1.3	+1.1	+1.4	...	...	...	...	...	...
20	50 25 N	213 37	...	67.3 N	.204	...	...	...	+0.2	−0.1	+0.1	0	0	–
20	49 49 N	214 36	23.3 E	...	...	+0.6	+0.6	+0.8	...	...	...	...	...	...
21	48 20 N	216 43	23.2 E	...	...	+0.6	+0.5	+0.7	...	...	...	...	...	...
21	47 34 N	217 53	22.8 E	...	...	+0.3	+0.3	+0.3	...	...	...	...	...	...
22	46 24 N	219 39	21.4 E	...	...	−0.9	−0.9	−0.8	...	...	...	...	...	...
22	45 47 N	220 30	...	65.3 N	.219	...	...	...	+0.1	+0.3	+0.1	+1	−2	–
22	45 28 N	220 53	21.1 E	...	...	−0.9	−0.9	−0.9	...	...	...	...	...	...
23	44 26 N	222 11	21.8 E	...	...	+0.1	+0.1	+0.1	...	...	...	...	...	...
23	43 54 N	222 53	20.8 E	...	...	−0.6	−0.5	−0.6	...	...	...	...	...	...
24	42 47 N	224 27	...	63.6 N	.230	...	...	...	−0.2	0.0	−0.2	+3	0	–
24	42 47 N	224 27	20.4 E	...	...	−0.6	−0.6	−0.6	...	...	...	...	...	...
24	42 08 N	225 29	19.4 E	...	...	−1.2	−1.3	−1.3	...	...	...	...	...	...
25	40 44 N	227 24	19.9 E	...	...	−0.1	−0.2	−0.1	...	...	...	...	...	...
26	39 49 N	229 56	19.4 E	...	...	−0.3	−0.3	−0.1	...	...	...	...	...	...
26	39 43 N	230 10	...	62.3 N	.242	...	...	...	0.0	+0.2	−0.1	+3	+2	–
26	39 24 N	231 22	19.1 E	...	...	−0.4	−0.5	−0.2	...	...	...	...	...	...
27	38 54 N	233 39	18.5 E	...	...	−0.5	−0.8	−0.4	...	...	...	...	...	...
Sep 5[e]	35 44 N	235 15	...	59.7 N	.258	...	...	...	−0.4	0.0	−0.3	+2	+3	–
5	35 05 N	234 36	17.2 E	...	...	−0.1	−0.2	+0.1	...	...	...	...	...	...
6	33 58 N	233 46	16.6 E	...	...	−0.2	−0.4	0.0	...	...	...	...	...	...
6	33 28 N	233 16	16.6 E	...	...	0.0	−0.2	+0.1	...	...	...	...	...	...
7	32 32 N	232 17	15.9 E	...	...	−0.4	−0.6	−0.4	...	...	...	...	...	...
7	32 29 N	232 13	...	56.0 N	.269	...	...	...	−0.3	+0.3	−0.1	−1	+2	–
8	31 22 N	230 45	15.3 E	...	...	−0.6	−0.6	−0.5	...	...	...	...	...	...
9	30 39 N	229 34	15.5 E	...	...	−0.1	−0.1	0.0	...	...	...	...	...	...
9	30 31 N	229 19	...	53.5 N	.277	...	...	...	−0.4	+0.4	−0.2	0	+3	–
9	30 06 N	228 38	14.8 E	...	...	−0.5	−0.6	−0.5	...	...	...	...	...	...
10	29 26 N	227 39	14.6 E	...	...	−0.4	−0.5	−0.4	...	...	...	...	...	...
11	28 17 N	225 50	...	50.6 N	.282	...	...	...	−0.4	+0.5	0.0	−1	+2	–
11	28 05 N	225 23	14.2 E	...	...	−0.4	−0.3	−0.3	...	...	...	...	...	...
12	27 36 N	224 05	14.0 E	...	...	−0.4	−0.3	−0.2	...	...	...	...	...	...
13	27 13 N	222 53	14.1 E	...	...	−0.1	−0.1	0.0	...	...	...	...	...	...
13	27 06 N	222 30	...	48.5 N	.285	...	...	...	−1.0	+0.3	−0.4	0	+3	–
14	26 38 N	220 57	13.3 E	...	...	−0.7	−0.6	−0.5	...	...	...	...	...	...
15	26 39 N	219 56	14.0 E	...	...	0.0	+0.1	+0.2	...	...	...	...	...	...
15	26 32 N	219 39	...	47.4 N	.285	...	...	...	−0.7	+0.4	−0.3	0	+3	–
15	26 24 N	219 07	13.4 E	...	...	−0.4	−0.4	−0.3	...	...	...	...	...	...
16	26 16 N	218 08	13.1 E	...	...	−0.6	−0.6	−0.4	...	...	...	...	...	...
17	25 21 N	216 46	12.5 E	...	...	−0.8	−0.9	−0.7	...	...	...	...	...	...
17	25 13 N	216 33	...	45.8 N	.286	...	...	...	−0.3	+0.7	+0.1	−1	+2	–
17	24 52 N	216 00	12.5 E	...	...	−0.7	−0.6	−0.4	...	...	...	...	...	...
18	24 08 N	214 42	12.7 E	...	...	−0.1	−0.1	0.0	...	...	...	...	...	...
18	23 50 N	213 53	12.0 E	...	...	−0.7	−0.6	−0.3	...	...	...	...	...	...
19	23 28 N	212 02	12.0 E	...	...	−0.4	−0.4	−0.1	...	...	...	...	...	...
19	23 25 N	211 42	...	42.9 N	.288	...	...	...	−0.3	+0.4	+0.2	−2	+2	–
20	22 56 N	208 58	11.9 E	...	...	−0.1	−0.1	+0.2	...	...	...	...	...	...
20	22 43 N	208 06	11.4 E	...	...	−0.5	−0.5	−0.2	...	...	...	...	...	...
21	22 21 N	206 48	11.5 E	...	...	−0.2	−0.2	0.0	...	...	...	...	...	...
21	22 18 N	206 35	...	40.7 N	.288	...	...	...	−0.3	+0.4	−0.1	−2	+1	–
21	22 13 N	205 56	11.4 E	...	...	−0.2	−0.1	0.0	...	...	...	...	...	...
22	21 51 N	204 39	11.2 E	...	...	−0.2	−0.1	0.0	...	...	...	...	...	...
22	21 39 N	203 55	11.1 E	...	...	−0.2	−0.1	0.0	...	...	...	...	...	...
23[f]	21 21 N	202 36	11.1 E	...	...	−0.1	−0.1	0.0	...	...	...	...	...	...

[e]The *Carnegie* was at San Francisco, California, during July 28 to September 3, 1929.
[f]The *Carnegie* arrived at Honolulu September 23, 1929.

Notes on Trip from Yokohama, Japan, to San Francisco, California, June 24 to July 28, 1929

After leaving Yokohama June 24, the first ten days were featured by light variable winds and calms. The engine was operated frequently and the average day's run was about 90 miles. Advantage was taken of a smooth, calm sea on June 27 and 28 to swing the vessel for deviations. One helm for declination-observations was made on June 27 before the clouds covered the Sun; all the next day was spent in making a swing with both helms for inclination and horizontal intensity.

About July 4 the region of cold surface-water was entered with practically one hundred percentage of clouds, mist, fog, drizzle, and rain, which continued until July 20. The wind was somewhat stronger, but not favorable. Adverse winds during July 9 to 12 drove the vessel 300 miles to the southward of the proposed track and the weather was so cold that the copper stove was used in the cabin from July 5 to 26. On July 14 the wind freshened from the southwest and for twenty days the average daily run was about 200 miles. Better weather was met between July 22 and 29, the wind still continuing fair and strong.

During the cloudy, foggy weather the program for declination was sadly interrupted. No observations could be obtained on July 6, 7, 12, 13, 14(I), and 19. On some of the other days, the observations were made with the Sun at such high altitudes and with such rough seas that the accuracy was seriously impaired. During the same period no balloon-flights could be made. The alternation of ocean-stations with magnetic stations was maintained throughout the trip, except that July 14 (II) and 15 were interchanged, on account of strong wind and rough sea. The ocean-station on July 15 was not successful below 500 meters. The messengers would not reverse the bottle owing to large wire-angle. For the later stations with strong wind, 170-pound lead weights were used on the end of the bottle wire, and the newer and heavier messengers were made still heavier by filling two drill-holes with lead, bringing the weight per messenger up to 13 ounces, as against 7 ounces for the ones previously used. These changes permitted securing temperatures and salinities down to 3,500 meters with wind-force 6.

The sonic-depth program was carried out as usual. Some difficulty was experienced owing to noisy microphones during high speed of the vessel through the water. No unusual variations in the depths were noted, except that on July 24 some irregularities were observed indicating the existence of several surfaces and some rapid changes in depth.

Tests with the new balloon sextant-theodolite-chair gave good results. The azimuths given by the chair differed from the regular theodolite by 1°.5 with an extreme range of 5° in thirty-five readings. A few improvements and more experience will decrease this range. Thus in rough water, when the balloon becomes lost to

the observer at the theodolite the observer at the sextant can carry on until the balloon disappears. Even now when the observer at the theodolite loses the balloon for a moment a glance at the azimuth-circle of the chair gives him the approximate theodolite-readings and enables him to relocate the balloon.

The first ocean-station after leaving Yokohama required seven hours to complete. Owing to strong currents the piano wire fouled the bottle wire and required some time and care to untangle and to avoid breakage and loss of wire, thermometers, and snapper. The current took the wires underneath the vessel, and the piano wire caught on the oscillator also. In an effort to locate and remedy the trouble the "divinhood" was used, but the rolling of the vessel nade the attempt dangerous on account of liability of helmet to be lifted off the head. However, sufficient depth was reached to show the trouble and a lead weight was then lowered along the piano wire, thus clearing it from the oscillator.

The new scheme of leaving the lead weights at the bottom has increased the efficiency of the bottom-sampling and decreased the time required. The 60-pound weight is in two halves, and each is suspended by a wire from the hook on the Sigsbee releasing-device which has been installed on the end of the shaft of Ross-type snapper. The bottoms of the two weights are fastened together by two staples driven in fairly tight. When the snapper hits bottom, the hook releases the wires allowing the two weights to fall apart outward from the top, thus forcing the lower staples out and the weights fall free. The snapper is driven into the ground with such force by the 60-pound weight that it has never failed to release the catches and it has come up full and closed. At two stations, the snapper was sent down twice, and was successful each time. On account of drift and limited length of wire, no bottom-sample was attempted on the days of high wind and rough seas. There is an economy of time, power, and personnel in using the main winch for the bottom-sampling instead of a separate machine. The only delay is on occasions when the pump could come up sooner but must wait until the bottom-sample is ready to come up.

The atmospheric-electric work has suffered some interruption because of bad weather, particularly in the few eye-reading diurnal-variation runs obtained. Unusually good potential-gradient traces, however, were secured, in spite of the foggy, misty, rainy weather.

Radio conditions were good and schedules were maintained every night. Exceptional cooperation has been shown by our amateur friends, and especially by the "San Francisco Examiner" radio station KUP.

The following observations were made during the period June 24 to July 29: 40 declinations, 18 inclinations and horizontal intensities, 2 atmospheric-electric runs, 26 complete potential-gradient traces, 12 pilot-balloon flights, 17 ocean-stations, and 166 sonic depths.

Notes on Trip from San Francisco to Honolulu, Territory of Hawaii, September 3 to 23, 1929

The entire trip of twenty days was featured by light airs and calms, with only a few days of regular trade-wind, the northeast trade-wind not appearing until September 17. The extremes in daily run were 66 to 177, average being 108.8 miles. The engine was used frequently. The new ball-bearing friction band on the winch installed at San Francisco has proven entirely successful. Several deep water-bottle series were sent down and brought up without any overheating or difficulty.

The new pelican bottom-snapper was successful on the first trial. On another occasion apparently it struck a whale at about 500 meters. On two occasions, the spring was not tight enough and the pressure of the water on inside of jaws as snapper went down rapidly was sufficient to open them, allowing the tongue catches to fall down closing the snapper, so that it struck bottom after being closed. Enough mud was secured from the outside of the jaws to examine for classification. The snapper came up full on four occasions, yielding about one and one-quarter liters of material, one sample weighing nearly two kilograms. It is expected that 100 per cent efficiency with this snapper will be had after final adjustments.

A peak or mountain which existing charts show at 32°.2 north and 128°.2 west, with a depth of fifty-eight hundred feet of water over it, was relocated thirty miles northeast of the above position, or at 32°.4 north and 127°.8 west, and with a least depth of forty-six hundred feet. It was named Hayes Peak in honor of Dr. Harvey C. Hayes of the Naval Research Laboratory, Washington, D. C., who developed the sonic depth-finder for the United States Navy. The slopes of the peaks are very steep, dropping off over eighty-five hundred feet in six miles. The peak rises out of a general depth of over fourteen thousand feet. Thus the peak is about ten thousand feet in height. The absence of soundings south and east leaves open the possibility that it may be a ridge instead of an isolated peak.

The new balloon-theodolite received at San Francisco is a decided improvement over the first one. The larger field of view permits keeping the balloon in sight continuously until it disappears due to distance. The new sextant-chair was used on several occasions to extend the time of observed flight, going to 59 minutes on one occasion. As the supply of six-inch uncolored balloons was low it was necessary to use black on several occasions, but their visibility was so poor that nine-inch uncolored balloons were used after that.

The regular program of observation was carried out and included 10 ocean-stations, 9 stations for dip and intensity, 27 stations for declination, 96 sonic depths, 11 potential-gradient and 10 conductivity traces, 14 pilot-balloon flights, and 4 evaporation-series.

The vessel arrived at Honolulu at noon, Monday, September 23, after an unusually quiet approach the previous night. The passage from San Francisco covered 2,186 miles.

PRELIMINARY VALUES OF THE ANNUAL CHANGES OF THE MAGNETIC ELEMENTS IN THE CARIBBEAN SEA AND THE PACIFIC OCEAN, AS DETERMINED FROM THE *CARNEGIE* RESULTS, 1909-1929, AND FROM THE *GALILEE* RESULTS, 1905-1908

By J. P. Ault and H. W. Fisk

This is the second paper giving the preliminary values of the annual changes of the magnetic elements for the various oceans, as deduced from all the observations on the *Galilee*, 1905-1908, and on the *Carnegie*, 1909-1929, including the results of Cruise VII to date. The first paper[1] gave the results for the North Atlantic, including Cruise VII observations from Washington, May 1, 1928, to Barbados, September 17, 1928. The present paper gives the results for the Caribbean Sea, the South Pacific Ocean, with a few values in the North Pacific Ocean, including observations of Cruise VII from Barbados, October 1, 1928, to San Francisco, July 28, 1929.

Various stations in the vicinity of intersections of Cruise VII, 1928-1929, with previous tracks have been utilized. The 1928-1929 values are not final, but the small corrections to be made at the completion of the cruise will not change the annual-change values given herein. The method used was the same as indicated in the first paper and as described on page 185 of Volume V, "Researches of the Department of Terrestrial Magnetism," use being made of the United States Hydrographic Office magnetic charts for 1925. The observations have not been corrected for diurnal variations since corrections for these are in general negligible for the times of observation on board the *Carnegie*.

The annual changes for the declination and inclination are referred invariably to the north-seeking end of the magnetic needle. Thus 9′ E means that the north-seeking end of the compass moved toward the east at the average annual-rate of 9′ during the period shown in the third column of the tables; 6′ S means that the north-seeking end of the dip needle moved upwards at the average rate of 6′ during the period shown in the third column. The progressive annual-change, or variation in the annual change with time, is given for many regions where the *Carnegie* has crossed more than twice. The localities have been arranged in accordance with decreasing northerly latitude.

The annual-change values determined by this preliminary discussion, show results consistent with those on recent charts. Declination is increasing (becoming greater east) in the southeastern Pacific and diminishing (becoming greater west) in the northwestern portion. The line of no annual change, however, lies nearer the western coast of South America than is generally shown. The inclination-results are such also as would be expected from previous data. The area of rapid increase in this element in the western Caribbean and off the coast of northwestern Peru is well

[1] J. P. Ault, *Terr. Mag.*, v. 34, 1929 (31-34).

shown by these results, and extends westward to the line of no annual change which appears to pass from the Gulf of Alaska past Hawaii to the region of Samoa. Inclination is increasing (algebraically) over the entire western Pacific, except the extreme northwest and along the coast of Japan where a few zero-values are indicated.

The annual-change values of horizontal intensity are not so consistent as are those of the other elements, as should be expected from the greater difficulty in measuring this element. Combinations of sea, wind, and course are apt to produce effects on the deflection-angle from which the intensity is computed of such magnitude as to affect the result greatly when all the observed values are used indiscriminately, as must be done in this preliminary report. It has been found possible to detect the individual values most seriously affected in this way by a more careful analysis. The cause is too complicated to permit of applying at present a correction with confidence, the process of analysis being laborious and slow. Final corrections as determined from this analysis and from laboratory investigations under way by W. J. Peters[2] in the Department will be included in the volume of final results to be published for all of Cruise VII. Meanwhile the preliminary results herein given for secular change in horizontal intensity will meet all practical needs with sufficient accuracy.

TABLE 1—*Average annual-changes for the Caribbean Sea*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		*years*	′	′	*c.g.s.*		
17.4 N	291.9	1910.6–1915.4	4.8	18W	......	....	6	5
		1915.4–1928.8	13.4	3W	......	....	5	7
		1910.6–1928.8	18.2	7W	......	....	6	7
		1910.6–1915.4	4.8	......	8 N	−.0011	3	4
		1915.4–1928.8	13.4	......	7 N	−.0006	4	2
		1910.6–1928.8	18.2	......	7 N	−.0007	3	2
16.5 N	299.7	1910.6–1928.7	18.1	10W	......	....	8	7
		1910.6–1928.7	18.1	......	5 N	−.0006	4	2
12.8 N	283.8	1915.2–1918.4	3.2	1 E	......	....	5	7
		1918.4–1921.8	3.4	3 E	......	....	7	6
		1921.8–1928.8	7.0	2W	......	....	6	6
		1915.2–1921.8	6.6	2 E	......	....	5	6
		1915.2–1928.8	13.6	0	......	....	5	6
		1918.4–1928.8	10.4	0	......	....	7	6
		1915.2–1918.4	3.2	......	9 N	−.0007	4	4
		1918.4–1921.8	3.4	......	10 N	−.0004	4	3
		1921.8–1928.8	7.0	......	7 N	−.0006	3	2
		1915.2–1921.8	6.6	......	9 N	−.0005	4	3
		1915.2–1928.8	13.6	......	9 N	−.0006	4	2
		1918.4–1928.8	10.4	......	8 N	−.0005	4	2

[2]Compare *Terr. Mag.*, v. 34, 1929 (93-115).

Table 2—*Average annual-changes for the Pacific Ocean*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		*years*	′	′	*c.g.s.*		
52.7 N	202.6	1916.7–1929.5	12.8	1 E	......	....	4	3
52.8 N	204.3	1916.7–1929.5	12.8	......	0	−.0002	3	1
50.6 N	188.4	1916.1–1929.5	13.4	2W	......	....	12	4
50.4 N	188.4	1916.1–1929.5	13.4	......	2 S	−.0002	10	2
		1907.6–1916.7	9.1	3 E	......	....	6	6
48.3 N	218.8	1916.7–1929.6	12.1	2 E	......	....	6	6
		1907.6–1929.6	22.0	2 E	......	....	6	6
		1907.6–1916.7	9.1	......	2 S	−.0001	6	4
47.8 N	217.0	1916.7–1929.6	12.1	......	0	−.0001	4	2
		1907.6–1929.6	22.0	......	1 S	−.0001	6	2
		1906.7–1916.1	9.4	7W	......	....	2	20
46.8 N	165.7	1916.1–1929.5	13.4	0	......	....	20	3
		1906.7–1929.5	22.8	3W	......	....	2	3
		1906.7–1916.1	9.4	......	1 S	.0000	2	11
46.2 N	166.0	1916.1–1929.5	13.4	......	1 S	.0000	11	2
		1906.7–1929.5	22.8	......	1 S	.0000	2	2
		1906.7–1916.7	10.0	5W	......	....	5	4
45.8 N	171.6	1916.7–1929.5	12.8	2W	......	....	4	3
		1906.7–1929.5	22.8	3W	......	....	5	3
		1906.7–1916.7	10.0	......	0	−.0001	4	3
46.1 N	173.1	1916.7–1929.5	12.8	......	0	−.0001	3	3
		1906.7–1929.5	22.8	......	0	−.0001	4	3
		1907.2–1916.7	9.5	1 E	......	....	9	11
43.1 N	221.7	1916.7–1929.6	12.9	2W	......	....	11	6
		1907.2–1929.6	22.4	1W	......	....	9	6
		1907.2–1916.7	9.5	......	1 S	.0000	7	7
43.1 N	221.4	1916.7–1929.6	12.9	......	1 N	−.0002	7	2
		1907.2–1929.6	22.4	......	0	−.0001	7	2
		1906.7–1916.6	9.9	6W	......	....	4	7
41.6 N	153.8	1916.6–1929.5	12.9	2W	......	....	7	4
		1906.7–1929.5	22.8	4W	......	....	4	4
		1906.7–1916.6	9.9	......	1 N	−.0002	4	4
42.3 N	155.3	1916.6–1929.5	12.9	......	0	+.0001	4	3
		1906.7–1929.5	22.8	......	1 N	.0000	4	3
		1907.6–1916.7	9.1	5 E	......	....	3	4
		1916.7–1921.1	4.4	4W	......	....	4	13
		1921.1–1929.6	8.5	1W	......	....	13	4
38.8 N	231.2	1907.6–1921.1	13.5	2 E	......	....	3	13
		1907.6–1929.6	22.0	1 E	......	....	3	4
		1916.7–1929.6	12.9	2W	......	....	4	4
		1907.6–1916.7	9.1	......	1 S	−.0001	3	4
		1916.7–1921.1	4.4	......	2 S	−.0003	4	7
		1921.1–1929.6	8.5	......	1 N	−.0002	7	1
39.0 N	230.9	1907.6–1921.1	13.5	......	1 S	−.0002	3	7
		1907.6–1929.6	22.0	......	0	−.0002	3	1
		1916.7–1929.6	12.9	......	0	−.0002	4	1
		1906.7–1916.6	9.9	4W	......	....	6	3
37.4 N	148.2	1916.6–1929.5	12.9	1W	......	....	3	12
		1906.7–1929.5	22.8	2W	......	....	6	12
		1906.7–1916.6	9.9	......	2 N	+.0002	5	3
36.9 N	148.5	1916.6–1929.5	12.9	......	0	−.0003	3	4
		1906.7–1929.5	22.8	......	0	.0000	5	4

TABLE 2—*Average annual-changes for the Pacific Ocean—Continued*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		*years*	′	′	*c.g.s.*		
		1906.6–1912.3	5.7	2W	......	....	7	6
		1912.3–1916.6	4.3	3W	......	....	6	4
		1916.6–1929.4	12.8	2W	......	....	4	7
		1906.6–1916.6	10.0	2W	......	....	7	4
		1906.6–1929.4	22.8	2W	......	....	7	7
30.8 N	143.3	1912.3–1929.4	17.1	2W	......	....	6	7
		1906.6–1912.3	5.7	......	3 N	−.0004	5	5
		1912.3–1916.6	4.3	......	5 S	+.0004	5	3
		1916.6–1929.4	12.8	......	1 N	+.0001	3	2
		1906.6–1916.6	10.0	......	1 S	−.0001	5	3
		1906.6–1929.4	22.8	......	0	.0000	5	2
		1912.3–1929.4	17.1	......	1 S	+.0002	5	2
		1906.6–1916.6	10.0	3W	......	....	4	5
		1916.6–1929.4	12.8	1W	......	....	5	6
28.1 N	144.5	1906.6–1929.4	22.8	2W	......	....	4	6
		1906.6–1916.6	10.0	......	0	−.0001	3	3
		1916.6–1929.4	12.8	......	0	+.0001	3	3
		1906.6–1929.4	22.8	......	0	.0000	3	3
19.0 N	166.5	1916.1–1929.4	13.3	0	......	....	26	5
		1916.1–1929.4	13.3	......	2 S	−.0002	15	2
18.9 N	156.9	1916.5–1929.4	12.9	1W	......	....	10	8
		1916.5–1929.4	12.9	......	3 S	+.0002	5	2
		1906.6–1916.6	10.0	3W	......	....	3	5
		1916.6–1929.4	12.8	1W	......	....	5	9
18.8 N	144.3	1906.6–1929.4	22.8	2W	......	....	3	9
		1906.6–1916.6	10.0	......	0	−.0001	4	6
		1916.6–1929.4	12.8	......	2 S	+.0002	6	2
		1906.6–1929.4	22.8	......	1 S	.0000	4	2
		1907.8–1912.3	4.5	2W	......	....	5	4
		1912.3–1916.5	4.2	1W	......	....	4	9
		1916.5–1929.4	12.9	1 E	......	....	9	7
		1907.8–1916.5	8.7	2W	......	....	5	9
		1907.8–1929.4	21.6	0	......	....	5	7
16.5 N	173.2	1912.3–1929.4	17.4	0	......	....	4	7
		1907.8–1912.3	4.5	......	6 S	+.0004	4	4
		1912.3–1916.5	4.2	......	4 S	−.0002	4	5
		1916.5–1929.4	12.9	......	3 S	.0000	5	2
		1907.8–1916.5	8.7	......	5 S	+.0001	4	5
		1907.8–1929.4	21.6	......	4 S	.0000	4	2
		1912.3–1929.4	17.1	......	3 S	.0000	4	2
		1906.5–1916.5	10.0	3W	......	....	2	10
		1916.5–1929.4	12.9	1W	......	....	10	8
16.0 N	156.6	1905.5–1929.4	22.9	2W	......	....	2	8
		1906.5–1916.5	10.0	......	5 S	−.0004	3	5
		1916.5–1929.4	12.9	......	3 S	+.0002	5	2
		1906.5–1929.4	22.9	......	4 S	.0000	5	2
15.6 N	149.8	1916.5–1929.4	12.9	1W	......	....	9	7
		1916.5–1929.4	12.9	......	2 S	+.0002	4	2
14.5 N	145.7	1906.5–1929.4	12.9	3W	......	....	4	7
		1906.5–1929.4	12.9	......	2 N	+.0001	4	2
		1912.4–1916.5	4.1	1W	......	....	5	7
9.6 N	179.4	1916.5–1929.3	12.8	2 E	......	....	7	6
		1912.4–1929.3	16.9	2 E	......	....	5	6

Table 2—*Average annual-changes for the Pacific Ocean—Continued*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		*years*	′	′	*c.g.s.*		
		1912.4–1916.5	4.1	......	11 S	−.0004	4	4
8.8 N	179.9	1916.5–1929.3	12.8	......	2 S	.0000	4	2
		1912.4–1929.3	16.9	......	4 S	−.0001	4	2
		1915.3–1918.3	3.0	2 E	......	....	6	7
		1918.3–1921.8	3.5	2 E	......	....	7	6
		1921.8–1928.8	7.0	0	......	....	6	3
		1915.3–1921.8	6.5	2 E	......	....	6	6
		1915.3–1928.8	13.5	1 E	......	....	6	3
5.2 N	280.2	1918.3–1928.8	10.5	1 E	......	....	7	3
		1915.3–1918.3	3.0	......	12 N	−.0001	4	4
		1918.3–1921.8	3.5	......	7 N	−.0006	4	3
		1921.8–1928.8	7.0	......	10 N	−.0003	3	2
		1915.3–1921.8	6.5	......	10 N	−.0003	4	3
		1915.3–1928.8	13.5	......	10 N	−.0003	4	2
		1918.3–1928.8	10.5	......	9 N	−.0004	4	2
		1915.3–1921.8	6.5	4 E	......	....	9	5
		1921.8–1928.8	7.0	1W	......	....	5	8
3.7 N	278.4	1915.3–1928.8	13.5	1 E	......	....	9	8
		1915.3–1921.8	6.5	......	9 N	−.0001	5	3
		1921.8–1928.8	7.0	......	10 N	−.0008	3	4
		1915.3–1928.8	13.5	......	9 N	−.0005	5	4
1.6 N	278.6	1918.3–1928.8	10.5	1 E	......	....	7	6
		1918.3–1928.8	10.5	......	9 N	−.0004	3	3
		1915.3–1921.7	6.4	5 E	......	....	9	7
		1921.7–1928.9	7.2	2 E	......	....	7	5
1.0 N	268.2	1915.3 1928.9	13.6	3 E	......	....	9	5
		1915.3–1921.7	6.4	......	6 N	−.0005	4	5
		1921.7–1928.9	7.2	......	0	.0000	5	2
		1915.3–1928.9	13.6	......	3 N	−.0002	4	2
		1915.3–1918.3	3.0	4 E	......	....	9	12
		1918.3–1921.8	3.5	4 E	......	....	12	7
		1921.8–1928.8	7.0	0	......	....	7	9
		1915.3–1921.8	6.5	4 E	......	....	9	7
		1915.3–1928.8	13.5	2 E	......	....	9	9
		1918.3–1928.8	10.5	1 E	......	....	12	9
0.6 N	274.9	1915.3–1918.3	3.0	......	14 N	+.0002	4	6
		1918.3–1921.8	3.5	......	7 N	−.0009	6	5
		1921.8–1928.8	7.0	......	5 N	.0000	6	3
		1915.3–1921.8	6.5	......	10 N	−.0004	4	5
		1915.3–1928.8	13.5	......	8 N	−.0002	4	3
		1918.3–1928.8	10.5	......	6 N	−.0003	6	3
0.6 N	185.6	1916.5–1929.3	12.8	3 E	......	....	9	8
		1916.5–1929.3	12.8	......	2 S	+.0001	5	2
		1906.4–1912.4	6.0	1W	......	....	5	12
		1912.4–1916.5	4.1	0	......	....	12	9
		1906.4–1916.5	10.1	1W	......	....	5	9
		1906.4–1929.3	22.9	1 E	......	....	5	8
0.3 N	181.1	1912.4–1929.3	16.9	2 E	......	....	12	8
		1906.4–1912.4	6.0	......	0	+.0002	5	5
		1912.4–1916.5	4.1	......	12 S	−.0005	5	5
		1906.4–1916.5	10.1	......	5 S	−.0001	5	5
		1906.4–1929.3	22.9	......	3 S	.0000	5	2
		1912.4–1929.3	16.9	......	5 S	.0000	5	2

TABLE 2—*Average annual-changes for the Pacific Ocean—Continued*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		years	′	′	c.g.s.		
5.0 S	260.8	1908.3–1921.7	13.4	6 E	......	....	2	5
		1921.7–1928.9	7.2	1 E	......	....	5	6
		1908.3–1928.9	20.6	4 E	......	....	2	6
		1908.3–1921.7	13.4	......	5 N	−.0001	2	2
		1921.7–1928.9	7.2	......	4 N	−.0002	2	3
		1908.3–1928.9	20.6	......	5 N	−.0002	2	3
5.2 S	253.2	1908.3–1912.6	4.3	4 E	......	....	5	8
		1912.6–1921.7	9.1	5 E	......	....	8	7
		1921.7–1928.9	7.2	1W	......	....	7	7
		1908.3–1921.7	13.4	5 E	......	....	5	7
		1908.3–1928.9	20.6	3 E	......	....	5	7
		1912.6–1928.9	16.3	2 E	......	....	8	7
		1908.3–1912.6	4.3	......	9 N	+.0001	6	4
		1912.6–1921.7	9.1	......	2 N	+.0001	4	3
		1921.7–1928.9	7.2	......	3 N	−.0002	3	2
		1908.3–1921.7	13.4	......	4 N	+.0001	6	3
		1908.3–1928.9	20.6	......	4 N	.0000	6	2
		1912.3–1928.9	16.3	......	3 N	.0000	4	2
8.7 S	188.6	1916.5–1929.3	12.8	2 E	......	....	8	11
		1916.5–1929.3	12.8	......	2 S	+.0002	3	3
10.6 S	277.8	1908.3–1918.2	9.9	0	......	....	5	9
		1918.2–1929.1	10.9	0	......	....	9	9
		1908.3–1929.1	20.8	0	......	....	5	9
		1908.3–1918.2	9.9	......	16 N	+.0002	5	5
		1918.2–1929.1	10.9	......	7 N	.0000	5	3
		1908.3–1929 1	20.8	......	11 N	+.0001	5	3
12.2 S	272.6	1918.2–1929.1	10.9	2 E	......	....	7	6
		1918.2–1929.1	10.9	......	6 N	−.0001	3	2
13.2 S	237 7	1917.0–1929.2	12.2	2 E	......	....	5	6
		1917.0–1929.2	12.2	......	1 N	−.0002	3	2
13.6 S	247.1	1912.6–1917.0	4.4	0	......	....	6	10
		1917.0–1929.0	12.0	3 E	......	....	10	16
		1912.6–1929.0	16.4	2 E	......	....	6	16
		1912.6–1917.0	4.4	......	4 N	−.0006	3	5
		1917.0–1929.0	12.0	......	2 N	−.0001	5	4
		1912.6–1929.0	16.4	......	3 N	−.0003	3	4
13.5 S	190.4	1906.8–1916.4	9.6	3 E	......	....	5	6
		1916.4–1921.5	5.1	2 E	......	....	6	11
		1921.5–1929.3	7.8	3 E	......	....	11	9
		1906.8–1921.5	14.7	3 E	......	....	5	11
		1906.8–1929.3	22.5	3 E	......	....	5	9
		1916.4–1929.3	12.9	3 E	......	....	6	9
13.5 S	190.4	1906.8–1916.4	9.6	......	6 S	−.0005	8	3
		1916.4–1921.5	5.1	......	3 S	.0000	3	5
		1921.5–1929.3	7.8	......	4 N	−.0001	5	3
		1906.8–1921.5	14.7	......	5 S	−.0003	8	5
		1906.8–1929.3	22.5	......	2 S	−.0003	8	3
		1916.4–1929.3	12.9	......	1 N	−.0001	3	3

TABLE 2—*Average annual changes for the Pacific Ocean—Continued*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual change: Declination	Average annual change: Inclination	Average annual change: Hor. Int.	Number of values utilized: First date	Number of values utilized: Second date
°	°		years	′	′	c.g.s.		
13.5 S	195.7	1906.8–1921.5	14.7	3 E	......	....	9	12
		1921.5–1929.2	7.7	4 E	......	....	12	12
		1906.8–1929.2	22.4	3 E	......	....	9	12
		1906.8–1921.5	14.7	......	5 S	−.0004	11	6
		1921.5–1929.2	7.7	......	8 N	−.0001	6	4
		1906.8–1929.2	22.4	......	1 S	−.0003	11	4
14.7 S	266.8	1918.3–1929.1	10.8	2 E	......	....	9	8
		1918.3–1929.1	10.8	......	5 N	.0000	5	2
14.7 S	234.4	1917.0–1929.2	12.2	2 E	......	....	15	9
		1917.0–1929.2	12.2	......	1 N	−.0001	9	2
14.7 S	257.2	1921.7–1929.1	7.4	2 E	......	....	5	6
		1921.7–1929.1	7.4	......	2 N	−.0004	2	2
15.8 S	281.0	1908.2–1918.1	9.9	1W	......	....	5	10
		1918.1–1929.0	10.9	3W	......	....	10	6
		1908.2–1929.0	20.8	2W	......	....	5	6
		1908.2–1918.1	9.9	......	13 N	+.0003	5	6
		1918.1–1929.0	10.9	......	5 N	−.0001	6	2
		1908.2–1929.0	20.8	......	9 N	+.0001	5	2
15.9 S	215.7	1907.1–1912.7	5.6	8 E	......	....	5	7
		1912.7–1921.0	8.3	3 E	......	....	7	8
		1921.0–1929.2	8.2	3 E	......	....	8	10
		1907.1–1921.0	13.9	5 E	......	....	5	8
		1907.1–1929.2	22.1	4 E	......	....	5	10
		1912.7–1929.2	16.5	3 E	......	....	7	10
		1907.1–1912.7	5.6	......	3 S	−.0003	5	4
		1912.7–1921.0	8.3	......	0	.0000	4	6
		1921.0–1929.2	8.2	......	5 N	−.0004	6	3
		1907.1–1921.0	13.9	......	1 S	−.0001	5	6
		1907.1–1929.2	22.1	......	1 N	−.0002	5	3
		1912.7–1929.2	16.5	......	2 N	−.0002	4	3
16.6 S	207.2	1912.8–1921.0	8.2	4 E	......	....	6	8
		1921.0–1929.2	8.2	2 E	......	....	8	9
		1912.8–1929.2	16.4	3 E	......	....	6	9
		1912.8–1921.0	8.2	......	1 N	−.0003	4	4
		1921.0–1929.2	8.2	......	3 N	−.0001	4	3
		1912.8–1929.2	16.4	......	2 N	−.0002	4	3
19.2 S	227.4	1917.0–1929.2	12.2	2 E	......	....	8	7
		1917.0–1929.2	12.2	......	2 N	−.0001	5	2
21.4 S	279.7	1918.1–1929.0	10.9	2W	......	....	11	4
22.1 S	279.4	1918.1–1929.0	10.9	......	4 N	−.0003	6	3
23.4 S	246.6	1908.2–1918.1	9.9	1 E	......	....	4	5
		1918.1–1929.0	10.9	1 E	......	....	5	7
		1908.2–1929.0	20.8	1 E	......	....	4	7
		1908.2–1918.1	9.9	......	4 S	−.0008	3	3
		1918.1–1929.0	10.9	......	5 N	−.0001	3	2
		1908.2–1929.0	20.8	......	3 N	−.0003	3	2

TABLE 2—*Average annual-changes for the Pacific Ocean—Continued*

Latitude	Longitude East of Gr.	Approximate dates	Time-interval	Average annual-change			Number of values utilized	
				Declination	Inclination	Hor. int.	First date	Second date
°	°		years	′	′	c.g.s.		
29.2 S	273.9	1913.0 1918.1	5.1	6W	......	....	4	5
		1918.1–1929.0	10.9	3W	......	....	5	4
		1913.0–1929.0	16.0	4W	......	....	4	4
		1913.0–1918.1	5.1	......	2 S	−.0004	4	2
		1918.1–1929.0	10.9	......	3 N	−.0003	2	2
		1913.0–1929.0	16.0	......	2 N	−.0003	4	2
30.6 S	243.8	1912.6–1917.0	4.4	2W	......	....	4	6
		1917.0–1921.7	4.7	2W	......	....	6	4
		1921.7–1928.9	7.2	6 E	......	....	4	7
		1912.6–1921.7	9.1	2W	......	....	4	4
		1912.6–1928.9	16.3	2 E	......	....	4	7
		1917.0–1928.9	11.9	3 E	......	....	6	7
		1912.6–1917.0	4.4	......	1 S	−.0003	2	3
		1917.0–1921.7	4.7	......	2 N	−.0003	3	3
		1921.7–1928.9	7.2	......	6 N	−.0003	3	2
		1912.6–1921.7	9.1	......	1 N	−.0003	2	3
		1912.6–1928.9	16.3	......	3 N	−.0003	2	2
		1917.0–1928.9	11.9	......	4 N	−.0003	3	2
30.8 S	250.8	1917.0–1921.7	4.7	2 E	......	....	10	3
		1921.7–1929.0	7.3	3 E	......	....	3	14
		1917.0–1929.0	12.0	2 E	......	....	10	14
		1917.0–1921.7	4.7	......	4 N	−.0004	5	4
		1921.7–1929.0	7.3	......	1 N	−.0003	4	4
		1917.0–1929.0	12.0	......	2 N	−.0003	5	4
33.1 S	269.8	1918.1–1929.0	10.9	2 E	......	....	4	5
		1918.1–1929.0	10.9	......	4 N	−.0002	3	2
36.4 S	255.2	1908.1–1913.0	4.9	4 E	......	....	5	6
		1913.0–1929.0	16.0	2 E	......	....	6	8
		1908.1–1929.0	20.9	2 E	......	....	5	8
		1908.1–1913.0	4.9	......	4 N	−.0002	4	6
		1913.0–1929.0	16.0	......	3 N	−.0004	6	3
		1908.1–1929.0	20.9	......	3 N	−.0003	4	3
38.7 S	263.2	1908.0–1912.9	4.9	4 E	......	....	4	5
		1912.9–1929.0	16.1	1 E	......	....	5	5
		1908.0–1929.0	21.0	2 E	......	....	4	5
		1908.0–1912.9	4.9	......	15 N	−.0006	5	4
		1912.9–1929.0	16.1	......	2 N	−.0003	4	2
		1908.0–1929.0	21.0	......	5 N	−.0004	5	2

DEPARTMENT OF TERRESTRIAL MAGNETISM,
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REVIEWS AND ABSTRACTS

(See also pages 286 and 325)

Palazzo, Luigi: *Misure magnetiche in Oltregiuba e Somalia nel 1926.* Roma, Mem. R. Ufficio Centrale di Meteorologia e Geofisica, Serie 3, v. 2, 1929 (63 con 4 tav.). 34 cm.

The results of the expedition of which this memoir is a detailed account and discussion have been reviewed in a previous issue of this Journal (see v. 33, 1928, pp. 90 and 100). In Part I, after making a general statement of his itinerary and the method of reaching the interior of this difficult country, the author describes the instruments used in the survey, giving particular attention to the details of a chronograph of his own devising, and used in observing oscillations of the long magnet in the determination of horizontal intensity. The instrument is a small portable type, readily carried in a case 30 by 23 by 20 centimeters with a total weight not exceeding 9 kilograms. It makes a record on a sheet 36 by 11 centimeters, on a drum 11 centimeters in diameter, driven by a clock-work device and controlled by a centrifugal regulator to make a revolution in approximately one minute. Two pens are provided, one moved by an armature actuated each half-second by an electric current from a dry-battery connected through the chronometer, the other operated by a key in the hand of the observer. The pens are arranged to move in opposite directions so that there is no confusion in reading the record, the indentations appearing on opposite sides of the pair of parallel lines. Reading the record is facilitated by use of a piece of transparent celluloid upon which six lines are engraved so as to divide the space between second-marks into fifths. To accommodate the slight variations in the speed of the drum the lines are drawn slightly convergent. The author does not claim an accuracy greater than that secured by a skilled observer using the eye-and-ear method, but under certain difficult conditions the advantages are obvious.

In the discussion of the constants of the magnetometer, it is pointed out that the principal magnet used in the same region in 1913, had a mean magnetic moment of 1136.37 ± 0.034; the magnetic moment derived from the more recent work thirteen years later was 1136.87 ± 0.037. The possibility that a real decrease in the magnetic moment has been slightly over-compensated by a decrease in the moment of inertia was recognized and discussed so far as possible without redetermining the latter. Evidence is found that the moment of inertia has not altered appreciably, but in any case the constancy of the magnetic moment for so long a time is noteworthy.

Part II of the memoir is devoted to a detailed description of the various places of observation which is supplemented in the appendix by reproductions of photographs made at each station. The observational data and results are given in full. Part III presents a discussion of the final values, with all components reduced to 1926.0. A magnetic chart (in colors) is given from 2° south latitude to 5° north latitude and from 41° to 46° east longitude. The memoir presents in convenient form the results of a survey carried out in a region not easily accessible, and thus supplies data where they were much needed.

H. W. Fisk

AURORAL OBSERVATIONS, RADIO RECEPTION, AND MAGNETIC CONDITIONS AT THE SITKA MAGNETIC OBSERVATORY, JULY 1928 TO JUNE 1929[1]

By Franklin P. Ulrich

This report is a continuation of the reports, begun in 1923, of the investigation concerning the relation between aurora and the Earth's magnetic field, and the effect of the Earth's magnetic field upon radio reception.

This year the work is divided into three parts (*a*) The observation of aurora at the Sitka Magnetic Observatory with a comparison of the Earth's magnetic field; (*b*) a record of daily radio reception with a comparison of the Earth's magnetic field; and (*c*) a log of auroral frequency.

Instruments and Methods.—The instruments and methods as outlined in the report for 1924 to 1925 were used during these observations. At Sitka the broadcast reception was received with an eight-tube superheterodyne receiver and the time-signals were received with a three-tube honeycomb coil receiver. The time-signals at 8^h and 18^h were received from Annapolis, at 11^h and 21^h from Mare Island, and at 15^h from Honolulu. All time given in this report has been reduced to standard 135th meridian time.

As in former reports[2] this summary consists of summations of all of the observations with deductions based on the year's observations and a comparison of these deductions with those of former reports. This summation includes the various phases of the aurora with a comparison of the Earth's magnetic field, radio reception, and the Earth's magnetic field and an auroral log with the Earth's magnetic field. It has been found that the radio-reception observations are becoming less valuable for the reason that new methods have been developed by which accurate observations can be made, which are not available at Sitka, and because of the discontinuance of cooperation by radio operators of other Government services in Alaska, so that hereafter the item of radio reception will be omitted from the report.

Aurora and the Earth's Magnetism—Aurora was observed three times during this period. During the appearance of the aurora on each of these occasions, a magnetic storm was in progress. Coronas: No coronas were observed during this period. Draperies: Draperies were observed only one time during this period, on December 1, 1928, from $0^h\,10^m$ to $0^h\,11^m$. During this time all of the elements were decreasing. This period is too short to form any deduction. Rays: Rays during aurora were observed at 24 separate times. During these times D was increasing 16 times and decreasing 16 times, H was increasing 20 times and decreasing 17 times, Z was increasing 16 times and decreasing 19 times. As in former years this would indicate that rays occur during aurora with no

[1]Published by permission R. S. Patton, Director, United States Coast and Geodetic Survey.
[2]For previous reports see *Terr.Mag.*, v. 30, 1925 (150-151) and v. 33, 1928 (162-165).

fixed relation to the condition of the Earth's magnetic field, the magnetic elements may be increasing or decreasing apparently independently of one another, but that they are changing and are not constant at that time. Diffused aurora: This form of aurora is the most common and usually accompanies the other forms. As with the rays this form appears with no fixed relation to the Earth's magnetic field.

The relation between radio reception and the Earth's magnetic field—The observations during this year were confined to those taken at Sitka only and consist of daytime long-wave reception (obtaining time-signals) and broadcast reception at night. There were 506 observations taken during the past year and the following table shows each group arranged according to reception and magnetic conditions.

Reception	None			Poor			Fair			Good		
Mag'c char.	0	1	2	0	1	2	0	1	2	0	1	2
Broadcast	38	19	4	24	17	2	56	14	3	41	23	1
Long-wave (daytime)	47	16	3	35	13	1	67	27	1	35	19	0
Totals	85	35	7	59	30	3	123	41	4	76	42	1

A study of the foregoing table indicates that during the past year the same deduction may be formed as in former years, namely that the condition of the Earth's magnetic field is no index of the way radio reception is received. Incidentally, radio reception during the past year was much poorer than during the previous year. The percentages of various receptions during 1927-1928 are as follows: None, 10; poor, 18; fair, 37; good, 35. The corresponding percentages during the year 1928-1929 are as follows: None, 25; poor, 18; fair, 33; good, 24.

Auroral frequency—Between October 1 and May 19 there were 84 nights which were clear or partly cloudy so that aurora could have been seen. On these 84 nights there were no auroras for 73 nights and of these 59 are classified as (0) magnetically and 14 as (1) magnetically. There were no (2)-days without aurora. Aurora in some form was noted or reported 11 times. These occurred on two (0)-days, five (1)-days, and four (2)-days. On the two (0)-days the aurora was a pale glow once and very faint the other time, and both times it was just along the sky-line in the north. These observations as in former years show that distinct auroras occur on magnetically disturbed days, but that there are magnetically disturbed days of character (1) on which no aurora occur.

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NOTE ON THE COMPUTATION OF THE MOMENT OF INERTIA OF A MAGNET AND ITS SUSPENSION

By C. R. Duvall

Abstract—A method of computation of the moment of inertia of a magnetometer-magnet is developed which gives a considerable saving of time over the method generally used. The reduction-formula is transformed so that the whole computation may be made by differential method.

The usual formula[1] for the computation of the moment of inertia K of a magnetometer-magnet and its suspension is

$$K=[T^2\left(\frac{5400}{5400-h}\right)(+(t-t')\,q)\,K_1]/[T_1^2\left(\frac{5400}{5400-h_1}\right)-T^2\left(\frac{5400}{5400-h}\right)(1+(t-t')\,q] \qquad (1)$$

In this equation K is the required moment of inertia at the temperature t during oscillations with the weight; K_1 is the moment of inertia of the weight at the temperature t, t' is the temperature during oscillations without the weight; q is the temperature-coefficient of the magnet; T and T_1 are the observed times, respectively, of an oscillation without and with the weight (oscillation here means the half-period); h and h_1 are the angles respectively, in minutes of arc, through which the magnet is turned without and with the weight by a turn of 90° of the torsion-head. Writing sd for h and sd_1 for h_1, in which s is the scale-value of the magnetometer in minutes of arc, and d and d_1 are the means in scale-divisions of all torsion-observations of the same fiber without and with the weight, respectively, equation (1) becomes

$$K=K_1/\{(T_1^2/T^2)[(1-sd/5400)/(1-sd_1/5400)]\,[1/(1-(t'-t)\,q)]-1\} \qquad (2)$$

This form of equation shows that the correction for rate of chronometer need not be applied to T_1 and T. Being the same proportion of both, the correction disappears in their ratio.

It will be much more convenient to compute with the time of the total number of oscillations, thus saving the work required to divide the observed time in each case by the corresponding number of oscillations. Let O and O_1 be the number of oscillations without and with the weight, respectively; then $T=OT/O$, $T_1=O_1T_1/O_1$, in which OT and O_1T_1 are the respective observed times of O oscillations without the weight and O_1 oscillations with the weight. Making these substitutions for T and T_1, writing A for $(O/O_1)^2\,(O_1T_1/OT)^2$ and writing r, r_1, and r_2, respectively, for the small quantities $sd/5400$, $sd_1/5400$, and $(t'-t)q$, equation (2) becomes

$$K=K_1/\{A[(1-r)/(1-r_1)]\,[1/(1-r_2)]-1\} \qquad (3)$$

[1]See for example p. 25 of "Directions for Magnetic Measurements," by D. L. Hazard, U. S. Coast Geod. Surv., Ser. No. 166, 1921.

Expanding and neglecting powers higher than the second of small quantities, equation (3) may be written

$$K=K_1/[A(1-r+r_1+r_2+r_1^2+r_2^2-rr_1-rr_2+r_1r_2)-1]$$

This becomes, on writing B for $A/(A-1)$

$$K=K_1/(A-1)[1+B(r_1-r+r_2+r_1^2+r_2^2-rr_1-rr_2+r_1r_2)]$$

Taking logarithms and retaining second powers of small quantities, we have, M being the modulus of common logarithms

$$\log K=\log K_1-\log (A-1)-MB\ (r_1-r+r_2)+MB\ [Br^2/2-(1-B/2)r_1^2-(1-B/2)\ r_2^2-(B-1)\ rr_1-(B-1)\ rr_2+(B-1)\ r_1r_2]$$

In the 5-place computations of observations made with the instruments of the Department of Terrestrial Magnetism the second powers of small quantities in the above expression have been found entirely negligible, so for the purpose of computing, the above equation may be written

$$\log K=\log K_1-\log (A-1)-MB\ s\ (d_1-d)/5400-MB\ q\ (t'-t) \quad (4)$$

Equation (4) gives log K at the temperature t during the oscillations with weight, the log K_1 being for the same temperature. We have log K_1 at t=log K_1 at $20°+0.0000165\ (t-20)$, in which 0.0000165 is derived from the coefficient of expansion of bronze, the metal of which the weight is made. Further, log K at $20°$= log K at $t+0.00001(20-t)$, in which 0.00001 depends on the coefficient of expansion of the magnet and suspension. Making these two substitutions in (4) we have

$$\log K_{20}=\log K_1 \text{ at } 20°-0.000130-MB\ s\ (d_1-d)/5400+0.0000065t \\ -MB\ q\ (t'-t)-\log\ (A-1) \quad (5)$$

The first three terms are combined into a constant for a series of observations, the fourth and fifth are small variable terms easily computed, while the sixth is the term requiring the main effort. Figure 1 shows a specimen application to the first three sets of a recent series of observations. Except for the instrumental constants q and s of the last column, lines 1 to 6 and 17 to 22 are from the data as observed. The last column is for computing quantities needed in the computation of the preceding columns, usually 6 in number. The work is carried forward as follows (1) Copy data for lines 1 to 6 and 17 to 22; (2) compute lines 23 and 24 of last column (usually mentally); (3) compute lines 7, 8, and 9 of other columns (most easily and accurately done with a computing machine); (4) complete the last column through line 34, using a Crelle multiplication table; (5) complete all other columns, using a Crelle for the multiplications.

The last term of equation (5), namely log $(A-1)$, may also be computed differentially. Let $(O_1T_1)_0$ and $(OT)_0$ be the respective

Computation of moment of inertia—Magnet 25L and suspension. Observer: W.F.W. Station: N_m, Washington, D.C. Weight, bar No.: 16

No.	Operation	Observations 1, 2	3, 4	5, 6	7, 8	9, 10	11, 12
1	Date, 1929 June	10	10	11	—	—	—
2	L. M. T.	h m 15 05	h m 15 52	h m 10 06	h m —	h m —	h m —
3	t	21.50	21.77	19.00	—	—	—
4	$t'-t$	−0.63	+0.23	0.00	—	—	—
5	O_1T_1	258.91	258.79	259.05	—	—	—
6	OT	236.80	236.56	236.94	—	—	—
7	$O_1T_1/OT = p$	1.09337	1.09397	1.09331	—	—	—
8	p^2	1.19546	1.19677	1.19533	—	—	—
9	$(O/O_1)^2p^2 = A$	2.34310	2.34566	2.34285	—	—	—
10	log constant	1.93611	611	611	—	—	—
11	$+(65/10^7)t$	+ 014	+ 014	+ 012	—	—	—
12	$-f_1(t'-t)$	+ 022	− 008	− 000	—	—	—
13	$-\log(A-1)$	−0.12811	− 894	− 803	—	—	—
14	$\Sigma = \log K_{20}$	1.80836	1.80723	1.80820	—	—	—
15	v	0	− 113	− 16	—	—	—
16	v^2	0	12769	256	—	—	—

Remarks:

*$804/10^7 = M/5400$

No.	Operation	Value
17	O	70
18	O_1	50
19	d_1	1.600
20	d	1.183
21	q	0.000452
22	s	1.97
23	O/O_1	1.4
24	$(O/O_1)^2$	1.96
25	$B = A/(A-1)$	1.74
26	$MB = 0.4343\ B$	0.756
27	$f_1 = MBq$	0.342
28	(d_1-d)	0.417
29	$s(d_1-d)$	0.821
30	$Bs(d_1-d)$	1.43
31	$-(804/10^7)Bs(d_1-d)$*	−0.000115
32	− constant	−0.000130
33	$\log K_1$ at 20°	1.936352
34	$\Sigma = \log C$	1.936107
35	Mean line 14	1.808359
36	$\log \pi^2$	0.994300
37	$\log \pi^2K_{20}$	2.80266

FIG. 1—Example of computation by equation (5)

times, to the nearest whole number of seconds, of O_1 oscillations with the weight and O oscillations without the weight. Writing $\triangle_1 = O_1T_1 - (O_1T_1)_0$, $\triangle = OT - (OT)_0$, $A_0 = (O/O_1)^2(O_1T_1)_0^2/(OT)_0^2$, $B_0 = A_0/(A_0 - 1)$, $r_3 = \triangle_1/(O_1T_1)_0$, and $r_4 = \triangle/(OT)_0$, equation (3) becomes

$$K = K_1/\{A_0[(1+r_3)/(1+r_4)]^2[(1-r)/(1-r_1)]1-r_2)-1\}$$

Proceeding as in the previous case we get

$$\log K_{20} = \log K_1 \text{ at } 20° - \log (A_0 - 1) - 0.000130 - MB_0 s\,((d_1 - d)/5400 + (65/10^7)\,t - MB_0\,q\,(t' - t) - [2MB_0/(O_1T_1)_0]\,\triangle_1 + [2MB_0/(OT)]_0\,\triangle + \text{second-order terms} \qquad (6)$$

The second-order terms are

$$+MB_0\,[B_0r^2/2 - (1 - B_0/2)\,r_1^2 - (1 - B_0/2)\,r_2^2 + (2B_0 - 1)\,r_3^2 + (2B_0 - 3)\,r_4^2 - (B_0 - 1)\,rr_1 - (B_0 - 1)\,rr_2 - 2\,(B_0 - 1)\,rr_3 + 2\,(B_0 - 1)\,rr_4 + (B_0 - 1)\,r_1r_2 + 2\,(B_0 - 1)\,r_1r_3 - 2\,(B_0 - 1)\,r_1r_4 + 2\,(B_0 - 1)\,r_2r_3 - 2(B_0 - 1)\,r_2r_4 - 4\,(B_0 - 1)\,r_3r_4]$$

These second-order terms are given in full so that the accuracy of the method may be tested when desired. It will be noticed that r and r_1 are constant for any one series of observations and enter into the results with opposite signs. In actual examples r_3 and r_4 have been found not far short of ten times as large as the other small quantities. The coefficient of r_3r_4 is probably the largest, so that appears to be a good term to examine.

The application of formula (6) is shown in Figure 2 for the data used in the specimen example above (Figure 1) on the basis of equation (5).

A large part of the work is the same as in the first example. Here the short columns beneath the main body of the computation and the right-hand column are also an auxiliary computation of quantities needed in the computation of the preceding columns and in the final result. In the present case the auxiliary computation is appreciably longer, actually having 8 more lines, two of which, however, are the mere setting down of the rounded-off times of oscillations. The last three lines beneath the main computation compute the single A_0 with the same accuracy as that of all the values of A in the first example. It is desirable to compute B_0, MB_0, $2/(O_1T_1)_0$, and $2/(OT)_0$ to four-figure accuracy so that the final three figures of f_2 and f_3 may have no computing error. Three-figure numbers are the largest that occur, and the computation is carried through the residuals to the probable errors with these numbers. The results of the two methods may be compared by comparing residuals. It will be noticed that lines 7 to 13 of the main computation are in units of the fifth decimal.

Computation of moment of inertia—Magnet: 25L and suspension. Observer: W.F.W. Station: N_m, Washington, D.C. Weight, bar No.: 16

No.	Operation	Observations 1, 2	3, 4	5, 6	7, 8	9, 10	11, 12
1	Date, 1929, June	10	10	11	—	—	—
2	L. M. T.	15h 05m	15h 52m	10h 06m	h m — —	h m — —	h m — —
3	t	21.50°	21.77°	19.00°	° —	° —	° —
4	$t'-t$	− 0.63	+ 0.23	0.00	—	—	—
5	Δ_1	− 0.09s	− 0.21s	+ 0.05s	s —	s —	s —
6	Δ	− 0.20	− 0.44	− 0.06	—	—	—
7	$+(65/10^2)t$	+ 14	+ 14	+ 12	—	—	—
8	$-10^5 f_1(t'-t)$	+ 22	− 8	0	—	—	—
9	$-10^5 f_2\Delta_1$	+ 53	+ 123	− 29	—	—	—
10	$-10^5 f_3\Delta$	− 128	− 282	− 38	—	—	—
11	Σ (7 to 10)	− 39	− 153	− 55	—	—	—
12	v	+ 1	− 113	− 15	—	—	—
13	v^2	1	12769	225	—	—	—

Op'n	Value	Op'n	Value	Op'n	Value
o	70	s	1.97	$\frac{(o_1T_1)_o}{(OT)_o} = n$	1.09283
o_1	50	o/o_1	1.4	n^2	1.19428
d_1	1.600	$(o/o_1)^2$	1.96	$A_o = (o/o_1)^2 n^2$	2.34079
d	1.183	$(o_1T_1)_o$	259		
q	0.000452	$(OT)_o$	237		

No.	Operation	Value
14	$B_o = A_o/(A_o-1)$	1.746
15	$MB_o = 0.4343\ B_o$	0.7583
16	$f_1 = MB_o q$	0.000343
17	(d_1-d)	0.417
18	$s(d_1-d)$	0.821
19	$B_o s(d_1-d)$	1.43
20	$2/(o_1T_1)_o$	0.007722
21	$f_2 = MB_o 2/(o_1T_1)_o$	0.00586
22	$2/(OT)_o$	0.008439
23	$f_3 = MB_o 2/(OT)_o$	0.006640
24	$-(804/10^7)B_o s(d_1-d)$*	− 0.000115
25	$\log K_1$ at 20°	1.936352
26	$\log \pi^2 - 0.000130$	0.994170
27	$-\log(A_o-1)$	− 0.127361
28	Mean line 11	− 0.000403
29	$\Sigma = \log \pi^2 K_{20}$	2.802643

Remarks:

*$804/10^7 = M/5400$

FIG. 2—Example of computation by equation (6)

The terms of the second order in r_3 and r_4 are $+0.0000222\ \triangle_1^2$, $+0.0000088\ \triangle^2$, and $-0.0000486\ \triangle_1\triangle$. The largest pair of values of $\triangle_1$ and $\triangle$ in any set of the 12 of this series is that for the second set, namely, $\triangle_1=-0.21$ and $\triangle=-0.44$. With these values the three terms above become $+0.000001$, $+0.000002$, and $+0.000004$. These terms are from 10 to 100 times larger than any other terms of the second order, hence it follows that in this case the computing error arising from the omission of the higher-order terms is about on the order of the rounding-off error.

These larger second-order terms in r_3 and r_4 depend on $\triangle_1$ and $\triangle$, which, in turn, depend on the values adopted for $(O_1T_1)_0$ and $(OT)_0$. If it is found desirable to reduce the magnitude of the values of $\triangle_1$ or of $\triangle$ or of both, $(O_1T_1)_0$ and $(OT)_0$ may be chosen to that $0^s.1$ which falls nearest to midway between the respective extreme values of O_1T_1 and OT. This refinement is really unnecessary as the case is not likely to occur where the computing error, resulting from the choice of $(O_1T_1)_0$ and $(OT)_0$ to the nearest whole second, is larger than that of the method heretofore used of computing with 5-place logs.

No more than 5-place logs is justified, however, as this number fully satisfies the condition of two uncertain figures. This appears from the probable error of a single set, which for this series of 12 sets is ± 0.00036. The second residual, -0.00113, is the largest of the series, and the probable error of the result is ± 0.00010.

The differential method brings out the effect of the different errors of observation. For example, the values of f_2 and f_3 show that if a single one of the 40 readings of the time of transit of the oscillating magnet, each made to $0^s.1$, had been read $0^s.1$ different from what it was, the result of the set would have been changed by 6 in the fifth decimal.

The fact that the computation may be made without loss of accuracy by the differential method brings to light the fact that a single column of the main body of the work, computed with mean values of times and temperatures, would give the final result with all necessary accuracy. If the computation is made this way, the first method by equation (5), Figure 1, is to be preferred. If the individual sets are computed, thus giving the data required for deriving the probable errors, then the second or differential method by equation (6), Figure 2, can be used with a very substantial saving of time and effort.

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A THEORY OF METEORS[1]

By H. B. Maris

ABSTRACT

High Speed Molecular Impacts—The energy of impact between a molecule of atmospheric nitrogen and a meteor moving 4×10^6 cm per sec is sufficient to vaporize 56 molecules of iron from the solid state to a gas at a temperature of $3000°K$, or is equal to the energy of an electron dropped through about 200 volts. It is assumed that where such energies are involved, we should expect the impact to result in a miniature explosion, which would drive from 10 to 100 molecules out of the main mass of the meteor.

Total Energy of a Meteor—The energy of the average meteor is observed to be dissipated within roughly 1.5 seconds after entering the upper atmosphere. It is shown that the resistance of the air to the solid mass of the meteor can account for only about one per cent of the total energy loss, and that radiation from the surface of the meteor can account for less than one per cent of the total radiation. It is concluded that most of the energy of the meteor is dissipated and changed to radiant energy by the high energy atoms and molecules which escape from the meteor and communicate their energy to the air by collision with air molecules.

Development of the trail—The meteor flashes into view when the energy of molecules escaping from it is sufficient to support the radiation of the trail. Impacts between air-molecules in the path of the meteor and escaping molecules prevent an increase in brilliancy as the meteor moves from the height of appearance to denser strata of air. At a height of about 60 to 80 km a compressed air-cap is formed in front of the meteor which prevents further direct impacts between stationary air-molecules and the meteor.

INTRODUCTION

Previous discussions of the appearance of meteors and their trails have been based on the assumption that the meteors are heated to a state of incandescence and rapid evaporization by friction with the gases of the upper atmosphere. The light was assumed to be due to the high temperature of the surface of the meteor and the surrounding gas-mantle. Upon further examination, however, these simple assumptions seem hardly tenable. They do not agree with the well established belief of many observers that telescopic meteors are often seen at an altitude of 500 to 1000 km.[2] At these heights the atmosphere is so rare that the surface could not be heated and there could be no surrounding gas-mantle. The total energy of the light emitted by the meteor can be explained as coming from the surface and an accompanying air-cap only by the assumption of temperatures which would be impossible for the material of the meteor, or an area of radiating surface of the meteor which is entirely inconsistent with the mass we would expect from calculations of its total kinetic energy. Moreover, the total possible air-resistance is not sufficient to give the observed radiation output without unreasonable assumptions as to the density of the air. The explanation of the observed facts of meteors and their trails given in the following pages, is based on the assump-

[1]Published by permission of the United States Navy Department.

[2]Olivier, Meteors, 1925, p. 151.

tion that the impacts of high-speed air-molecules cause miniature explosions of ten to a hundred molecules from the surface of the meteor. Sparrow[3] and Lindemann and Dobson[4] have recognized clearly the importance of direct impacts. Sparrow has assumed that heating of the meteor is due principally to them, while Lindemann and Dobson have held that most of their energy would be dissipated by the escape of high energy atoms, leaving the main mass of the meteor cold. No attempt was made, however, to explain the features of the meteoric trail as the direct result of these escaping high energy molecules.

For the purposes of the present discussion a meteor of the following characteristics is assumed, velocity 4×10^6 cm sec^{-1}, mass 6.25×10^{-5} grams of iron, cross sectional area 10^{-2} cm^2, and a visible path of length 6×10^6 cm. These are the characteristics which Lindemann and Dobson ascribe to a first-magnitude meteor, calculating the mass of the meteor from the energy of the emitted light. The arguments of this paper do not depend very critically upon the assumed characteristics, although it turns out later that a little heavier meteor gives a better agreement with the observations.

HIGH SPEED MOLECULAR IMPACTS

It must be emphasized at the very beginning that no one knows exactly what happens when a particle moving with a velocity of 40 km sec^{-1} strikes a solid. Although laboratory experiment gives no complete answer to the problem certain positive-ray experiments, such as cathode sputtering, have a bearing on the question. In the cathode-sputtering chamber positive ions with velocities of the order 10^2 km sec^{-1} (assuming ions of a mass 10^{-23} gram to fall 2 cm in a field of 10^3 volts cm^{-1}) strike the cathode and cause vaporization of the metal of the cathode and radiation of the spectrum lines characteristic of the metal. In brief, this is a case where the energy of the flying particle is known to produce other effects than purely elastic collisions or direct heating. Table 1 gives a number of illustrations of what a gas-molecule moving with a velocity of 40 km sec^{-1} may do. Column (1) gives the molecule, column (2) its kinetic energy in ergs, column (3) the number of molecules of a gas of specific heat 0.20 cal gram^{-1} degree^{-1} which are raised 2000°K in temperature if they should receive all the energy of the fast moving molecule, column (4) the number of molecules which would be excited to a 15-volt excitation-level, column (5) the number of hydrogen molecules which would be dissociated into atoms and each atom ionized (taking the dissociation- and ionization-potentials to be 2.7 and 13.5 volts, respectively), and column (6) the number of iron atoms which would be changed from the solid state at 0°K to a vapor at a temperature of

[3]SPARROW, *Astroph. J.*, v. 63, 1926 (90).

[4]LINDEMANN AND DOBSON, *Proc. Roy. Soc.*, v. 102, 1922 (418).

$3000°K$. Column (7) gives the energy, expressed in equivalent volts, which a gas-molecule of column (1) would receive from an inelastic collision with an iron atom moving with a velocity 40 km sec^{-1} (assuming conservation of energy and momentum throughout); the column shows that the energies are high.

TABLE 1—*Effects of impact of gas molecules at 40 km sec*$^{-1}$

(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Number of Molecules				
Gas	Total Energy	Heated 2000°	Excited to 15-volt level	H_2 molecules dissociated and ionized	Fe vaporized to 3000°	Energy
	ergs					*volts*
N_2	37.0×10^{-1}	900	14	8	56	155.
O_2	42.3	1020	17	9.	64	169.
A	52.8	1280	20	11.	79	185.
Kr	109.5	2660	43	22.	165	279.
He	5.3	129	21	1.6	8	31.1
H_2	2.6	64	10	8.	4	16.2
Fe	73.9	1740	29	15.	...	.....

We would expect the energies of column (2) at the instant of an impact to be immediately transferred to some of the forms indicated by columns (3) to (7). We would expect radiation to come after this transfer as a result of a temperature- or excitation-change. We see from the table that a nitrogen molecule upon striking the iron meteor would immediately give up energy sufficient to raise the temperature of a thousand atoms of iron to the melting point. It hardly seems probable that the energy could be so evenly distributed that no atom would be ionized, excited, evaporated, or broken loose from the main body of the meteor. One iron atom escaping from the meteor would, in a small fraction of a second, transfer its energy of motion or double the energy of the original impact to the surrounding atmosphere by secondary collision. Thus if 98 per cent of the energy of the original impact went to heat the meteor, the energy dispersed into the atmosphere would still be at least twice that of the direct resistance of the air to the motion of the meteor, but as has been pointed out by Lindemann and Dobson (*loc. cit.*, p. 423), very little of the energy of impacts of air-molecules goes to heat the main mass of the meteor. In fact we know that a meteorite which enters the atmosphere with energy sufficient to vaporize 180 times its mass reaches the Earth cold and with little more than the velocity of a freely falling body in the air. In this case all of the energy with which the meteorite entered the air was carried away by molecules leaving it.

We may then think of the direct impact of the high-speed gas-molecule as causing a miniature explosion on the surface of the

meteor which hurls atoms, molecules, and possibly fragments of molecular dimensions away from the meteor. These atoms, molecules, and small fragments travel along with the main mass of the meteor, until they lose their energy through impacts with air-molecules. Radiation would then come principally from these secondary impacts. This is in keeping with the hazy appearance of telescopic meteors which are seen at heights of 500 to 1000 km since at these elevations meteoric fragments might easily have a free-path of 1000 km after ejection from the meteor before the first impact with an air-molecule which might occur several km from the meteor. The meteoric glow described by many observers as a hazy glow in the region of the radiant of a meteoric shower is probably produced by these escaped high-speed atoms.[6,7]

TOTAL ENERGY

The total possible release of energy from inelastic collisions of the meteor with air-molecules would at 100 km, the height of appearance, be given by the equation

$$E=MV^2/2=DA\,V^3/2=2\times10^8 \text{ ergs per second} \qquad (1)$$

where E is the energy of inelastic collisions, M the mass of air swept up per second ($M=DV$, where D is the density of the air at this height, see column (3), Table 2), A is the cross-section area of the meteor, and V is the velocity of the meteor in centimeters per second. The radiation from the average first-magnitude meteor was calculated by Lindemann and Dobson to be 3×10^{10} ergs per second, or 100 times the possible input, assuming a per cent of visible energy equal to that of solar radiation. As has been pointed out by Sparrow, this is a very improbable assumption and the total outflow of energy is more apt to be 5 to 25 times as great as that given, but an outflow of even 3×10^{10} ergs per second from the surface of the meteor is equal to the radiation from a black body of the same size at a temperature of 19,000°K. This is obviously an impossible temperature since the material of the meteor would all volatilize at 2000°K, when radiation from the meteor would be approximately 10^8 ergs. We must then assume that the energy of the meteor-trail can not be changed from energy of motion to radiant energy at the surface of the meteor, but this change must take place in the air surrounding the meteor.

Table 2, taken from an earlier paper[8], gives certain facts about the atmosphere in regions where the meteors appear. Column (1) gives the altitude above sea-level, column (2) the pressure, column (3) the density, and column (4) the mean free-path of the air-molecules. If we consider the first-magnitude meteor as entering the air with the velocity given, all of its energy must be dissipated

[6] TROWBRIDGE, *Astroph. J.*, v. 26, 1907 (104).
[7] OLIVIER, Meteors, 1927, p. 152.
[8] *Terr. Mag.*, v. 34, 1929 (45-53).

TABLE 2—*Atmospheric data for the temperature condition of summer night*

(1) Altitude	(2) Pressure	(3) Density	(4) Mean free-path
km	*dynes cm²*	*grams cm³*	*cm*
60	1.6×10^{2}	2.1×10^{-7}	3.2×10^{-2}
80	8.9	1.2×10^{-8}	5.8×10^{-1}
100	5.02×10^{-1}	6.5×10^{-10}	$1.0\times10^{+1}$
120	3.38×10^{-2}	4.4×10^{-11}	$1.5\times10^{+2}$

in a period of 1.5 seconds. The meteor can lose energy in three ways: By radiation; by the loss of energy to air-molecules (conduction); and by the loss of high-energy atoms or molecules of its own mass (convection). If we assume a temperature of 3000°, which is 700° above the temperature assumed by Lindemann and Dobson, and radiation from the front surface only, the energy loss in 1.5 seconds is 2×10^{8} ergs. or only 0.4 per cent of the total energy. Pickering has used this argument of the maximum possible radiation from the meteor's surface to prove that the radiating surface of the meteor must be greater than that assumed by Lindemann and Dobson. However, the surface of the meteor increases as the square of the radius, whereas the mass, and hence the kinetic energy to be dissipated, increases as the cube and the assumption of a larger meteor would only intensify the difference between the energy to be dissipated as compared with what could be radiated.

If the total energy of the meteor were expended in warming the surrounding air, it would heat a cylinder 20 cm² in cross-section to a temperature of 10,000° for the entire length of its path. Since the cross-section of the meteor is only 10^{-2} cm² hardly one per cent of the total energy can be expended directly in heating the air. We are then forced to the conclusion that the meteor assumed by Lindemann and Dobson will dissipate approximately 99 per cent of its energy into the surrounding air by the loss of its own mass.

DEVELOPMENT OF THE TRAIL

The mean free-path of a gas-molecule is 10 cm at the height where the meteor appears and 0.6 cm at the height of disappearing. Since the velocity of a meteor is much greater than the average velocity of an air-molecule, the free-path of an escaping molecule relative to the meteor λ_m is given approximately by the equation

$$\lambda_m = 2\lambda_1 \, V_1/V_2 \qquad (2)$$

where λ_1 is the free-path of the air-molecule, V_1 is the velocity of the molecule relative to the meteor, and V_2 the velocity of the meteor relative to the air. At the height of appearance a molecule leaving the meteor with a velocity relative to the meteor of 8×10^{4}

cm per sec would travel an average of 4mm or more than four times the diameter of the meteor before striking an air-molecule. The ratio of the molecules struck in the path of the meteor to those struck which are not in the path of the meteor is very roughly given by the equation

$$\beta=\pi r^2/(2/3)\ \pi\lambda^2{}_m=d^2/8\lambda^2{}_m \qquad (3)$$

where d is the diameter of the meteor. In the case assumed λ_m is equal to 0.4 cm at the position of appearance of the meteor, and to 0.024 cm at the height of disappearance; from (3) the respective values of β are 0.01 and 3. If we assume that the impact of each air-molecule which strikes the meteor with a velocity of 40 km per second results in the escape of x molecules with an average velocity of 8×10^4 cm sec^{-1}, we may, since we know the value of β at 100 and at 80 km, and since we know the brightness of the meteor is constant and the total number of molecules escaping from the meteor is approximately the same at 80 km as at 100 km, solve for the value of x. Let Z be the number of molecules in the path of the meteor at 100 km and K be the number which strike the meteor. The number of molecules driven from the path of the meteor is given by $Z-K=0.01\ Kx$ at 100 km and $17Z-K=0.75\ Kx$ at 80 km; whence $x=27$. We have in this solution assumed a constant diameter for the meteor; the error in this assumption is probably largely compensated by the assumption that the temperature of the meteor remains constant, which of course is not true. The value of x would be expected to increase with an increase in the temperature of the surface of the meteor. As the meteor moves down in the atmosphere the number of molecules increases, but since the mean free-path of the molecule is shorter the high-speed molecules from the meteor sweep more of the air-molecules from its path, thus decreasing the per cent of direct impacts and explaining the failure of the average meteor to increase in intensity as it moves to lower and denser strata. This would be true for values of x equal to approximately 30. For greater values of x, the beginning of the trail would be brighter, and for smaller values fainter, than the end of the trail. The result is very similar to the result assumed by Lindemann and Dobson, but they have assumed that the energy of radiation is from heat generated by adiabatic compression; here the assumption is made that high-speed molecular impacts break loose the molecules from the cold surface of the meteor and excite and ionize the atoms in the air.

Columns (4), (6), and (7) of Table 1 show that at a velocity of 40 km per second, the air-molecules have much more than sufficient energy to break up the molecule and generally much more than sufficient energy to excite and ionize the atoms. Therefore, the assumption is made that the molecular or atomic excitation which gives the light of the meteor-paths is produced not by the mass-action of compression, adiabatic or otherwise, but is the result of a large number of high-speed impacts between individual atoms or molecules. The well-established fact that meteoric trails occasion-

ally remain visible for several minutes and have been observed for nearly an hour after the passage of the meteor supports this assumption. The glowing trails differ in color for different meteors and only one in ten thousand leaves a persistent trail, therefore we are forced to assume that the visibility of the trail depends on the material of the meteor and not on the atmosphere or condition of fall. The persistence of the trail is limited to heights of 75 to 100 km, evidently by air-pressures at those heights. The trail, which is cone-shaped with the small end of the cone down, increases in diameter with a time-ratio which indicates gas-diffusion. The center of the cone is much less luminous than the edges. This would seem to exclude oxidation or any ordinary type of chemical reaction as a means of releasing the energy to support luminosity, since the mass of oxygen, roughly 10^6 grams, included within the cone, which is often several kilometers in diameter, is much more than would be required to support combustion. The best assumption would therefore seem to be that the luminosity of the persistent meteor-trail is that of an excited gas. Active nitrogen gas in the presence of a small quantity of metal vapor often glows for several minutes after the excitation has been discontinued.[9]

GAS-CAP

The foregoing discussion of meteor-trails at heights greater than 80 km can not be considered as applying to the trails at lower altitudes. For example, according to equation (3) at 60 km of 1300 molecules escaping from the meteor, 1299 would strike an air-molecule in the path of the meteor and one would strike a molecule not in the path of the meteor. It is obvious that at this altitude (3) does not apply and hence the direct escape of high-speed molecules would play a minor part in the formation of the trail. Below 80 km we would expect the appearance of the trail to be explained by the formation of a gas-cap in front of the meteor. The flow of energy into this cap is given by equation (1). As explained by Sparrow the equations of adiabatic compression can not be used because the gas of the cap is not in a state of equilibrium. On the other hand, the equations for action between spheres used by Sparrow are not applicable because those equations assume elastic impacts between spheres, and elastic impacts involving the energies of column (7), Table 1 are very improbable.

RADIATION OF THE METEOR-TRAIL

Visible radiation is emitted by electron drops of 2 to 4 volts, while column (7) of Table 2 shows that the energy of complete inelastic impact of an air-molecule with a meteoric mass is generally over 150 volts, which is equivalent to the ionization potential of very soft x-ray radiation; we would expect then a large per cent of the radiation of the meteor-trail to be in the ultraviolet or even soft x-ray region as suggested by Lindemann and Dobson (*loc. cit.*,

[9]CONSTANTINIDES, *Phys. Rev.*, v. 30, 1927 (95).

p. 418). Some of this energy would be absorbed by the surrounding gas and emitted as visible light (for example, oxygen becomes fluorescent under the influence of "entladungstrahlen"), but this would probably account for only a small part of the total energy. Under these conditions it is thought that an efficiency of visible radiation of 10 per cent as compared with the Sun would be a conservative assumption. If this assumption is made the first-magnitude meteor of Lindemann and Dobson which appears at a height of 100 km and disappears at 80 km after traversing a path of 6×10^6 cm will dissipate 5×10^{11} ergs. It will have a mass of 6.25×10^{-2} gram, a diameter of 0.248 cm and a cross-sectional area of 0.0534 cm^2. It will sweep out 1.4×10^{-3} gram of air and will do 1.12×10^{10} ergs of work against the air if we assume each molecule of air in the path received a velocity of 4×10^6 cm sec^{-1} and that the area of the meteor remains constant throughout the path. Thus less than 0.02 of the energy of the meteor will be expended directly against air-resistance and the remaining 0.98 must be spent as suggested by Lindemann and Dobson (*loc. cit.*, p. 418, 423), in ionization- and excitation-impacts beyond the main mass of the meteor which lead to radiation of light.

If the source of radiant energy is assumed to be a gas-cap, the first-magnitude meteor radiating with the efficiency just assumed will reach the brilliancy of a first-magnitude star at a height of 60 km. It is possible that the double maximum in the heights of disappearance of meteors observed by Lindemann and Dobson is due to the formation of a gas-cap at an altitude of 70 to 80 km. We would expect the smaller meteors to disappear with the formation of this shielding cap, but the larger meteors having a mass sufficient to form and maintain a brilliant cap would maintain their brilliancy until the pressure of the air-cap had reduced their velocity to a few kilometers per second.

The conclusions concerning the luminosity of meteor-trails may be summarized briefly. The high-velocity impacts of air-molecules with the body of a meteor result in the ejection from the meteor of a mass of molecular fragments approximately 30 times the mass of the original air-molecules. A meteoric trail increases in brightness with descent of the meteor to denser air-strata until a height is reached at about 100 km where about 50 per cent of the air-molecules are prevented from striking the meteor by being driven from its path by the flying fragments of former impacts. As the air-density increases with lower altitudes, a greater per cent of the air is driven from the path and there is little increase in the number of direct impacts or in brilliancy. The light of a high meteoric trail comes principally from ionization and excitation resulting from impacts between air-molecules and these molecular fragments of the meteor. At about 80 km a gas-cap forms in front of the meteor and at lower altitudes the light of the trail comes principally from the gas-cap.

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RESOLUTIONS PASSED BY THE COMMISSION FOR TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY OF THE INTERNATIONAL METEOROLOGICAL COMMITTEE AT COPENHAGEN, SEPTEMBER 1929[1].

On September 12 and 13, 1929, two meetings of the International Commission for Terrestrial Magnetism and Atmospheric Electricty were held at Copenhagen, Denmark, and the following officers were elected President, Ch. Maurain; Secretaries, D. la Cour and G. van Dijk. Thirteen new members were also elected representing twelve different countries, namely, S. Banerji (India); T. F. Claxton (Hongkong); J. Egedal (Denmark); J. A. Fleming (U. S. A.); Hlasek (Poland); J. Keränen (Finland); G. Ljungdahl (Sweden); P. L. Mercanton (Switzerland); A. Nippoldt (Germany); J. Patterson (Canada); N. Rose (U. S. S. R.); H. U. Sverdrup (Norway); A. Wigand (Germany). Among the subjects discussed at these meetings were the following: Relations between the Commission and the Section of Terrestrial Magnetism and Electricty of the International Geodetic and Geophysical Union, investigations of the daily lunar variation in the Earth's magnetic field, manner of measuring magnetic traces, and proposals regarding the projected polar year 1932-33.

On September 14, 1929, a joint meeting of the Commission for the Réseau Mondial and Polar Meteorology and the Commission for Terrestrial Magnetism and Atmospheric Electricty was held. After considerable discussion the following eight resolutions were adopted unanimously:

1—The Conference is of the opinion that magnetic, auroral, and meteorological observations at a network of stations in the arctic and antarctic would materially advance present knowledge and understanding of the magnetic, auroral, and meteorological phenomena not only within the polar regions but in general. The Conference is also of the opinion that this increased knowledge will be of practical application to problems connected with terrestrial magnetism, marine and aerial navigation, wireless telegraphy, and weather-forecasting.

2—The Conference is of the opinion that such observations should be carried out for one whole year and that international cooperation both in making the observations and collecting and disseminating them is necessary to ensure this.

[1]Abstracted by H. D. Harradon from the minutes of the meetings supplied by the Secretary, D. la Cour.

3—The Conference proposes that such international cooperation shall be established during the year 1932-33, which is the Jubilee Year of the first International Polar Year in 1882-83.

4—The Conference has received a Report of a Sub-Commission appointed by the Commission for the Réseau Mondial and Polar Meteorology and the Commission for Terrestrial Magnetism and Atmospheric Electricity to consider the question of the proposed Polar Year, and is of the opinion that the scheme there outlined forms a suitable basis for the scientific work to be undertaken.

5—The Conference appoints a new Commission to be entitled "The Commission for the Polar Year 1932-33," to be charged with the carrying out of the undertaking. This Commission will prepare detailed plans of the observations to be made and the methods of making them and will take all steps possible to coordinate the work of the various countries and organizations taking part so that the greatest value may be obtained from the scientific work carried out during the Polar Year.

6—The Conference appoints: The President of the Commission for the Réseau Mondial and Polar Meteorology (Dr. G. C. Simpson), the President of the Commission for Terrestrial Magnetism and Atmospheric Electricity (Prof. Ch. Maurain), the President of the Commission for the Exploration of the Upper Air (Pro . Dr. H. Hergesell), Dr. D. la Cour (Denmark), M. Karpinsky (Russia), Mr. J. Patterson (Canada), Dr. H. U. Sverdrup (Norway), to be members of the Commission with power to add to their number representatives of countries which express their intention of taking an active part in the Polar Year.

7—The Conference instructs the Bureau of the International Meteorological Organization to bring the scheme for the Polar Year to the notice of all Directors and Governments in order to obtain the international cooperation on which the scheme depends.

8—The Bureau is also instructed to issue an invitation to the International Union of Geodesy and Geophysics to support the undertaking and to appoint representatives to cooperate with the "Commission for the Polar Year 1932-33."

In the course of the discussion considerable attention was given to the suggestion that the Polar Year should be postponed for 4 or 5 years as the year 1932-33 was expected to be a year of minimum sunspots. However, there was a preponderance of opinion amongst the members of the Commissions that the Polar Year should take place in 1932-33, on accont of the interest which would be caused by celebrating the Jubilee of the previous Polar Year 1882-83.

At the meeting of the Conference of Directors held on September 17, 1929, the eight proposed resolutions given above, were accepted, and Dr. D. la Cour was chosen President of the new Commission for the Polar Year 1932-33.

PROVISIONAL SUNSPOT-NUMBERS FOR JULY TO NOVEMBER, 1929

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	July	Aug.	Sep.	Oct.	Nov.	Day	July	Aug.	Sep.	Oct.	Nov.
1	71	66	9	47	..	17	70[b]	115	38[d]	37	67
2	82	70[a]	17	53	81	18	70	*W*107[c]	17	26	67
3	86	47	31	64	..[bd]	19	73	43	20	18	49
4	65[a]	*E* 37[c]	28	55[b]	92	20	73[aa]	*E* ..[c]	*W* 43[c]	19	44
5	*W*67[dc]	41	*M* 49[c]	55	129	21	100	..	55	32	44[ad]
6	68[b]	56[ad]	49	*E* 64[c]	100[d]	22	78	74[a]	44[a]	22	41
7	79	61[d]	*M* 62[c]	74[d]	80	23	63	*M* 67[c]	35	33	51[d]
8	73	48	54	68	91	24	*E* 50[c]	54	13	17[d]	60[d]
9	*M*57[c]	54	58	76	80[bd]	25	40	54	10	..	81
10	73[b]	*M* 61[c]	56	84[b]	94	26	*M* 46[c]	*E* 47[c]	*E* 23[c]	*M* 36[c]	90
11	95[d].	*E* 62[acc]	39	77	71	27	67	32	25	*M* 68[c]	119[b]
12	79	74[a]	31	79[b]	68[a]	28	58[a]	32	17	97[a]	127[a]
13	86	*M* 76[ac]	53	78[b]	*E* 82[c]	29	45[b]	27	43[d]	57	146[b]
14	76[d]	*M*101[c]	25	63	..[a]	30	*E* 43[c]	28	40[a]	76[b]	..[b]
15	92[d]	132	32	56	93[a]	31	60[d]	10		*E* 69[c]	
16	88	125[ab]	26	40	65[ad]						
						Means	70.1	62.1	34.7	54.7	81.2
						No. days	31	29	30	30	26

Mean for the quarter July to September, 1929: 55.6 (90 days)

*a*Passage of an average-sized group through the central meridian.

*b*Passage of a larger group through the central meridian.

*c*New formation of a large or average-sized center of activity: *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, in the central zone.

*d*Entrance of a large or average-sized center of activity on the east limb.

Zürich, Switzerland W. Brunner

NOTE ON A THEORY OF THE PERMANENT MAGNETIC FIELDS OF THE SUN AND EARTH

Dr. J. Bartels has recently pointed out in a letter to the Editor of this Journal that in the writer's paper on "A theory of the permanent magnetic fields of the Sun and Earth"[1] the step from equation (4) to equation (5) in neglecting the first term of the bracket in (4) is not clearly indicated. In the derivation it was foreseen that the terms which would contribute to the drift-currents would be terms containing higher powers of sin θ than the first, since the effects must be averaged over all values of θ from 0 to 2π. The term which Dr. Bartels points out should be retained was multiplied into sin θ which when averaged with respect to θ, reduced to zero. Thus the final form of the expression is as given in (5).

[1]*Phys. Rev.*, v. 34, 1929 (335-343); *Terr. Mag.*, v. 34, 1929 (154).

Professor Leigh Page has recently pointed out to the writer that the derivation which was given is incomplete when one considers drift-currents arising from crossed electric or gravitational and magnetic fields since in this type of field, a drift-motion is imposed on the ion which is independent of the angle θ and has a sign opposite to the term which depends on the angular distribution. Professor Page has worked out the complete theory of the ion-drift imposed by crossed electric and magnetic fields.[2] He finds (equation 8) that the net ion-drift current-density is zero when an average is taken over two dimensions or is given by

$$i_x = Ne^3\lambda^2 E_y H_z/54\ mkT \tag{1}$$

when the motions are averaged over all three dimensions. The symbols have the significance of the original paper. This current which corresponds to the "normal" Hall effect is opposite in sign to the current which was originally assumed to demagnetize the Earth and was attributed to the internal crossed electric and magnetic fields. The change in sign has necessitated a revision of the original conclusions since these currents actually magnetize the Earth. A shift of the emphasis in the theory from currents arising from an inhomogeneous magnetic field to currents arising from crossed electric and magnetic fields therefore becomes necessary.

The new viewpoint removes the major objection to the original form of the theory which required that the mean free-path of the electrons within the Earth approximate the abnormally large value of 3×10^{-6} cm. By attributing the entire current-system to ion-drifts arising from crossed electric and magnetic fields the free-path necessary to give the observed steady field is readily calculated. A mean westward current-density throughout the Earth's core and crust of approximately 4×10^{-11} ab. amp. per cm^2 is necessary to explain the observed magnetic moment of the Earth. Taking the internal radial electric field arising from the gravitational separation of charge as 0.3 c m. u. per cm, $e=1.59\times 10^{-20}$, $H=0.5$ gauss, $n=10^{23}$ ions per cc and the mean internal temperature as 5,000° then the mean free-path necessary to account for the observed currents can be calculated from equation (1). Substituting in this equation the necessary mean free-path of the ion turns out to be 2×10^{-7} cm, a value much less than the free-path necessary on the original work which attributed the primary currents to an inhomogeneous magnetic field. Ion free-paths of this length are readily allowable in the core of the Sun or Earth. A calculation shows that ion-drifts due to an inhomogeneous magnetic field or due to gravity are unimportant if the free-path has a value no larger than that just given.

The conclusion that the current-system arises from the internal radial gravitational-electric field of the Earth crossed with its self-produced magnetic field simplifies certain requirements, as we have seen, but it has introduced another difficulty. This dif-

[2] *Phys. Rev.*, v. 34, 1919 (763-771).

ficulty arises from the fact that the system of magnetic fields and currents which have been introduced are essentially unstable and the mechanism that controls the final magnitude of the field is not clear. Indeed it is more difficult to explain why the Earth's magnetic field is so small than it would be to explain a field a thousand times as large. Several possible factors which might control the steady state present themselves and these will be investigated. The questionable points which have arisen in connection with the theory have nearly all been related to the problem of electrical conduction in solids and it seems probable that no final conclusion can be reached in the present case until the more elementary problems of conduction are satisfactorily explained. The calculations on the Hall effect, for example, are known to be often in disagreement with experimental facts not only as to magnitude, but as to sign, and until this difficulty is removed the original theory should, perhaps, not be entirely discarded.

Ross Gunn

Naval Research Laboratory, Washington, D. C.,
October 18, 1929

ZODIACAL LIGHT AND MAGNETIC STORMS

From April 1853 to April 1855 Rev. George Jones, U. S. N., observed the zodiacal light every night, weather and other things permitting. A comparison of his record with the Greenwich magnetic storm-list gave the following results: In this period there were 26 magnetic storms, or storm-groups, and 23 periods of abnormal zodiacal light, 16 of which followed within three days after a magnetic storm. Ten storms occurred on dates for which there were no zodiacal-light observations, and there were seven cases of abnormal zodiacal light with no accompanying magnetic storms listed. The abnormalities in the light were mainly fluctuations, and sometimes an unusual brilliance or distribution in the heavens. In the years 1911 to 1929 mention was found of five cases of abnormal zodiacal light. Four of these are followed closely by magnetic storms, the fifth occurring at an epoch of magnetic calm. All in all the data give a rough average interval of less than two days for the lapse of time between the storm and the zodiacal-light manifestations.

The correspondence between zodiacal-light behavior and magnetic disturbance indicates, but does not prove, that the light comes from particles originating from the terrestrial atmosphere, in accord with the views of Barnard and others. It seems possible to sketch out a qualitative theory by considering the behavior of the high-flying terrestrial ions under the influence of gravitation, light-pressure, and the terrestrial magnetic field.

E. O. Hulburt

Naval Research Laboratory, Washington, D. C.

ON THE THEORY OF SOLAR CORONA

The outer atmosphere of the Sun is assumed to be composed mainly of charged particles, which are actuated by gravitation, radiation-pressure, and the magnetic field of the Sun. By distillation along the lines of magnetic force the particles collect in the lower latitudes of the solar outer atmosphere and by their diamagnetism and drift-currents reduce the magnetic field approximately to zero in this region, leaving a stray field at the poles. Thus the coronal streamers, prominent during sun-spot minima, are regarded as owing their form to the magnetic field of the Sun. Whereas the wide-spreading structureless coronal luminosity extending out from the lower latitudes is due to an accumulation of ionization which reduces the magnetic field to a low value and permits the radiation to blow the particles out to great distances. During maximum solar activity there is sufficient ionization of the outer atmosphere to reduce the magnetic field to a low value even at the poles, and hence the outer atmospheric spray extends roughly equally in all directions, in accord with the appearance of the corona.

E. O. HULBURT

Naval Research Laboratory, Washington, D. C.

PRINCIPAL MAGNETIC STORMS

SITKA MAGNETIC OBSERVATORY

APRIL TO SEPTEMBER, 1929[1]

(*Latitude 57° 03′.0 N.; longitude, 135° 20′.1, or 9^h 01^m.3 W. of Gr.*)

Greenwich mean time								Range		
Beginning				Ending				Decl'n	Hor. int.	Ver. int.
1929		h	m	d	h	m		′	γ	γ
Apr.	4	8	04	5	05	..		49.1	518	410
Apr.	15	17	..	17	17	..		80.6	941	527
May	13	3	..	14	03	..		44.4	503	481
July	10	7	38	11	05	..		58.6	572	586*
July	14	16	35	17	15	..		141.8	866	655*
July	31	20	09	2	12	..		99.7	921*	522*
Aug.	14	12	30	15	14	..		80.2	507	395*
Sep.	6	23	28	8	03	..		119.1	561	669
Sep.	10	1	..	10	13	..		56.1	445	393
Sep.	22	2	55	22	24	..		99.6	933	805

*Curve went off the paper in one direction.

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

During the quarter April to June there were no magnetic storms of sufficient intensity or unusual characteristics to warrant reproduction. While the storm of April 15-17 shows a large range in the horizontal intensity it is not a large or active storm. This large range is caused by an abnormally large but slow increase at one time and about ten hours later by an abnormally large and slow decrease.

There were no particularly large magnetic storms during the third quarter.

July 31-August 2, 1929—*H* began to decrease rapidly beginning at $13^h 00^m$ August 1; at $13^h 13^m$ the *H*-reserve spot went off the paper making a range of 676 gammas in 13 minutes. At $13^h 36^m$ the reserve-spot came back on the paper and rapidly increased 567 gammas between $13^h 36^m$ and $14^h 03^m$. From there on *H* increased spasmodically for several hours until it finally reached normal.

September 22, 1929—This was a moderately active storm with the greatest activity between 9^h and 14^h. During the 10^h *H* decreased 565 gammas in 18 minutes.

FRANKLIN P. ULRICH, *Observer-in-Charge.*

CHELTENHAM MAGNETIC OBSERVATORY
JULY TO SEPTEMBER, 1929[1]

(Latitude 38° 44'.0 N.; longitude 76° 50'.5 or $5^h 07^m.4$ W. of Gr.)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Ver. int.
1929	*h*	*m*	*d*	*h*	*m*	′	γ	γ
July 10	11	36	11	02	..	27.6	192	109
July 14	16	30	18	..	..	32.0	84	80
July 31	21	10	2	07	..	30.3	212	131
Aug. 14	12	30	15	11	..	30.1	135	96

GEO. HARTNELL, *Observer-in-Charge*

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey; see also description of storm on July 14-18 in *Terr. Mag.* vol. 34, p. 262.

HUANCAYO MAGNETIC OBSERVATORY
MAY TO AUGUST, 1929

(Latitude 12° 02'.7 S.; longitude 75° 20'.4 or $5^h 01^m$ W. of Gr.)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Ver. int.
1929	*h*	*m*	*d*	*h*	*m*	′	γ	γ
July 10	11	35	10	23	..	11.5	342	46
July 14	16	32	16	20	..	7.0	324	34
July 31	21	07	2	08	..	10	230	27
Aug. 14	12	27	15	07	..	4	387	32

July 10, 1929—Beginning with a sudden increase of 64γ in two minutes in horizontal intensity at $11^h\,35^m$ and a sharp increase in declination at about the same time, there was a short magnetic storm on July 10, which was characterized chiefly by large rapid fluctuations in horizontal intensity, and by marked disturbances in declination and vertical intensity. The disturbance moderated at about 19^h and ended before 23^h.

July 14-16, 1929—A prolonged magnetic disturbance, not severe enough to be called a storm except for a few hours during the daily maximum on July 16, began suddenly on July 14 at $16^h\,32^m$ with a sudden increase of 61γ in four minutes in horizontal intensity, but no marked change in declination or vertical intensity. There was no great disturbance indicated during the following two days except for low values of horizontal intensity during the nights of July 14 and 15 and for the sharp disturbance during the few hours of the daily maximum on July 16.

August 14-15, 1929—A mild magnetic storm beginning with small but very sudden increases in all three elements. For seven hours declination and vertical intensity show rapid, small fluctuations and thereafter were practically undisturbed. Horizontal intensity was characterized by like disturbances superimposed upon the normal diurnal change except for two hours from $17^h\,30^m$, when three large but temporary decreases followed one another. Following the third decrease there was an increase of 190γ in 18 minutes; thereafter, though subnormal, there were only slow and small fluctuations with a gradual rise to normal. The time of ending was indefinite.

July 31–August 2, 1929—This mild magnetic storm began with an increase of 59γ within five minutes in horizontal intensity, a marked increase of 7γ in vertical intensity, and a small but marked decrease in declination. Thereafter until 11^h, August 1 only horizontal intensity was markedly disturbed and that only by occasional moderate fluctuations. At exactly 11^h the disturbance in all elements became very marked, with the daily maximum in horizontal intensity replaced by a large depression upon which were superposed moderate but rapid fluctuations. At 21^h the disturbance began to moderate, declination and vertical intensity being then very little disturbed while horizontal intensity increased gradually to normal also at about 6^h, August 2.

All times given are Greenwich civil mean time.

PAUL G. LEDIG, *Observer-in-Charge*

REVIEWS AND ABSTRACTS

(See also pages 286 and 300)

MEYER, RUDOLF. *Die Haloerscheinungen.* Hamburg, Verlag von Henri Grand, 1929 (viii+168 mit 2 Tafeln und 22 Figuren im Text). 23 cm.

Unusual and striking meteorological manifestations have at all times made an impression on the minds of those witnessing them, and among those peculiarly apt to appeal to man's imagination are halos and their attendant phenomena. In ancient times these rings encircling the Sun and Moon were often regarded as omens portending some misfortune or calamity although, at times, more favorable interpretations were put upon them. The sayings still current, particularly with reference to the influence of halos on weather-changes, indicate the popular opinions to which their occurrence gives rise.

The work under review which is the twelfth volume of the collection entitled "Probleme der Komischen Physik," is not merely a summary of our present knowledge of the subject but it represents as well an attempt to set forth the manifold relations between halos and other phenomena and especially to indicate what problems are at the present time susceptible of solution. The author states that he has endeavored to show that halo-phenomena have an independent place among the problems of cosmical physics and that his book is addressed not only to the specialist but also to the general reader whom he hopes to interest and encourage in observing these appearances.

The treatise is divided into four main parts: (1) Description of observational data—general description and comparative frequency of various forms, their relation to the Sun's altitude, their brightness, color, and polarization; the secular variation of halo-frequency and its relation to sunspots; halos considered in connection with cloudiness and weather conditions. (2) The general basis for an explanation of halo-phenomena—historical introduction, observational and experimental investigations of the forms of ice-crystals in which halos originate; size, arrangement, color, motion, and quantity of such crystals; polarization, diffraction, and refraction of light by crystals, etc. (3) Special explanation of the individual forms of halo-phenomena— ordinary halo of 22°, parhelia, Parry and Lowitz arcs, halo of 46°, circumzenithal and circumhorizontal arcs, lateral tangent arcs of the 46° halo, parhelic circle, parenthelia, light pillars, etc. (4) Introduction to the practical execution of halo-observations—directions for making suitable drawings and descriptions and for obtaining satisfactory photographs.

Among the problems requiring solution the following may be mentioned: Suitable designations of the different halos by names and symbols, measures or at least estimates of the brightness of halos, investigation of polarization, density of cloud, and the relation of halos to kind and degree of cloudiness as well as to general weather-conditions.

In discussing the fundamental principles of explanation, the author has dealt with a number of questions which are usually only touched upon in works

on meteorological optics, as for example, investigations of the number of ice-crystals in the clouds, the brightness of halo-phenomena, and the limits of their perceptibility in connection with cloud-density and general brightness of the cloudy heavens, as well as the polarization and diffraction of halo-light.

Throughout the work mathematical treatment has been avoided.

H. D. HARRADON

HULBURT, E. O.: *Ions and electrical currents in the upper atmosphere of the Earth.* Phys. Rev., Menasha, Wis., v. 34, No. 8, Oct. 15, 1929 (1167-1183). (Author's summary preceding article.)

It is assumed that the ionization in the upper atmosphere is caused by the ultraviolet light of the Sun and that the ion- and electron-densities at noon at the equator are in keeping with the facts of wireless waves. From the laws of recombination of the ions and of diffusion and drift of the ions in the Earth's magnetic, gravitational, and electric fields the distribution of the ions over the Earth is worked out. The distribution is found to agree with wireless data over the Earth, and with Gunn's diamagnetic theory of the solar diurnal-variation of the Earth's magnetism (Phys. Rev., v. 32, 1928, pp. 133-141). The gravitational drift-currents are found to flow mainly along the parallels of latitude in the following way: (1) a current-sheet in the daylight hemisphere flowing eastward in the levels above 150 km which at the sunrise and sunset longitudes divides into two sheets: (2) one of these flows westward on the day side of the Earth underneath (1) in the levels below 150 km, and (3) the other sheet continues eastward around on the night side of the Earth. The current is mainly (4/5) between the 40th parallels of latitude north and south, and falls to lower values at the higher latitudes. The total currents of the three sheets are about 1.16×10^7, 8.7×10^6, and 2.9×10^6 amperes, respectively. The east and west daytime current-sheets subtract from each other leaving in effect an eastward current of about 2.9×10^6 amperes flowing around the Earth all the time. This causes a magnetic field agreeing in magnitude and type with that obtained by Bauer in his 1922 analysis of the magnetic field of the Earth of external origin (Terr. Mag., v. 28, 1923, pp. 1-29). The current-sheets are not of the type required by Chapman's drift-current theory of diurnal magnetic-variation (Proc. R. Soc., A, v. 122, 1929, pp. 369-386). As a result of the drift-currents, the sunset longitude of the Earth is at a potential around 2000 volts above that of the sunrise longitude. This electric field combined with the Earth's magnetic field causes the ions and electrons on the night side of the Earth to drift upward with velocities between 100 and 200 cm. sec^{-1}. The ions and electrons move into regions of lower pressure and therefore do not recombine as fast as they otherwise would. This removes a difficulty from an earlier calculation which yielded a slightly too great rate of disappearance of the free charge at night. The upward drift of the ionization causes a rise of the Kennelly-Heaviside layer which is, partially at least, compensated for by the fall due to the cooling and contraction of the atmosphere at night, and is complicated by the diffusion of the ions. It is difficult to say how much of the nighttime rise of the layer observed in experiments with wireless rays may be a genuine rise and how much may be an apparent rise due to delayed group-velocities, or to other causes.

NOTES

28. *Auroral Station of Alaska Agricultural College and School of Mines*—Following the recommendation of the American Geophysical Union, U. S. Coast and Geodetic Survey, and Department of Terrestrial Magnetism, the Executive Committee of the Rockefeller Foundation, passed, on November 8, 1929, a resolution appropriating to the Alaska Agriculture College and School of Mines the sum of $10,000 for the purpose of establishing, equipping, and maintaining a first-order auroral station at College, near Fairbanks, Alaska, for carrying out a five-year program of research on the aurora. Thus the resolution adopted at the Prague meeting of the International Geodetic and Geophysical Union regarding the desirability of having at least one pair of photographic stations for the purpose of measuring the height and situation of the aurora is being put into effect as far as the United States is concerned. The site chosen is particulary favorable for this purpose. In addition to physical and cultural considerations, it has a unique advantage as regards geographical position, being practically 180° distant in longitude from the first-order auroral station in Norway the existence of which was likewise made possible through the generosity of the Rockefeller International Education Board.

29. *Auroral Photography at Lerwick Observatory*—In October 1928, a Krogness auroral camera was brought into use at the Lerwick Observatory which was established mainly for observations of terrestrial magnetism, atmospheric electricity, and the aurora. Since then every possible opportunity has been taken to obtain photographs of the aurora. This work is being carried out in cooperation with Professor Carl Störmer, of Oslo, whose very important work in connection with the investigation of the aurora is well known.

30. *Magnetic Observatory at Karssani* (*Georgia*)—On account of the electrification of the urban tram-lines, the magnetic observations were transferred in 1905 from Tiflis to the village of Karssani not far from the Mzchetha station on the main line from Tiflis to Bâtun, about 20 km from Tiflis. We now learn from the *Meteorologische Zeitschrift* that owing to the proposed gradual electrification with direct current of the Tiflis-Chaschuri section which passes at a distance of only 1 km from the magnetic observatory at Karssani, magnetic observations will have to be discontinued ultimately at the latter point also. In view of this contingency, the Geophysical Observatory of Georgia has had under consideration since 1927, the timely removal of the observations from Karssani to some other locality and part of the instruments for the new station have already been ordered from the Askania-Werke in Germany. The selection of the new site is rendered difficult by the mountainous nature of the region surrounding Tiflis and the continual extension of tram-line electrification but a decision will be reached in the near future. It is proposed to make parallel magnetic observations at Karssani and the new station for at least one year's time.

31. *Geophysical Institute, Prague*—We have received from the Czechoslovak National Geophysical Institute, of which Dr. V. Láska is director, the first issue of the "Bulletin Magnétique" in which it is purposed to present the detailed results of observations made at the two Czechoslovak magnetic observatories one of which is situated at Praha (Prague) and the other at Stará Dala (O'Gyalla). This first number contains the hourly values of the magnetic declination obtained at Stará Dala (47° 52'.5 north latitude, 18° 11'.4 east longitude) during 1927 and 1928 as derived from the curves registered at the Observatory. As is known, this Observatory ceased to function because of conditions brought about by the World War. As a result of the efforts of Drs. J. Kaván and A. Dittrich, the various obstacles have been overcome and it was possible to recommence systematic observations at the beginning of the year 1923. It is hoped, however, that in future numbers of the Bulletin more complete magnetic results may appear.

32. *Magnetic Activity in U. S. S. R.*—We have read with much interest the account of the Second Geomagnetic Conference held in Leningrad last April as published in the Bulletin de Magnétisme Terrestre et d'Electricité Atmosphérique, No. 13. In the interval of five years which have elapsed since the First Conference in 1924, there appears to have been a general increase in interest in terrestrial magnetism as manifested in the establishment of new observatories, in the extension of field-observations, and the development of magnetic methods of prospecting. There were, however, some less favorable circumstances as, for example, the discontinuance of magnetic observations at the Odessa Observatory and the possible interruption of magnetic work at Sverdlovsk because of electric-car effects, and the slow progress in the organization of some of the new observatories.

In addition to the existing observatories which are to serve as a basis for the magnetic survey of U. S. S. R., now in progress, it was thought expedient in the course of the next five years to establish observatories at Askabad, Alma-ata or Zaisansk, and in the region of the Kuznetsk coal-basin. In order to accelerate as much as possible the work of the magnetic survey, it was decided to adopt a cooperative plan whereby certain stations should be assigned for occupation to individual institutions thus assuring a total of about 273 stations during the next five years. In making determinations at field stations an accuracy to 1' in declination and inclination, and to 0.0005 of the value in horizontal intensity is to be attempted. It is hoped to publish in the near future, under the auspices of the Central Geophysical Observatory, charts of the general distribution of the magnetic elements in U. S. S. R., which it is proposed to bring up to date every five years according to the development of the work. In addition to the general charts, sectional and special charts are to be issued for use of navigation, aviation, etc. A proposal was also made with regard to keeping a record of all known anomalies and the adoption of a standard type of needles for inclinometers.

33. *Isogonic Chart of Mexico for 1930*—We have received from the Magnetic Section of the Astronomical Observatory of Tacubaya, an isogonic map of the Republic of Mexico for the epoch 1930, scale 1:5,000,000. (Mapa de la República Mexicana; líneas aproximadas de igual declinación para 1930.) The map is in colors and the declination curves are drawn at intervals of 20' in red. It is pub-

lished by the Dirección de Estudios Geograficos y Climatológicos, Secretaría de Agricultura y Fomento, 1929. Its dimensions are 37 by 60 cm.

34. *New edition, Isomagnetic World-Charts, U. S. Navy Department*—The Hydrographic Office of the United States Navy Department is issuing the third edition of their isomagnetic charts of the world for the year 1930. Of these charts, that for declination (No. 2406) has been completed and those for inclination (No. 1700) and for horizontal intensity (No. 1701) will be ready for distribution at the beginning of 1930. In the preparation of these charts, the Hydrographic Office has utilized for the ocean-areas, in addition to the sea observations of the Navy, the observations obtained on previous cruises of the *Carnegie* as well as those obtained on the present cruise (VII) as far as Honolulu. These charts exhibit the excellence of workmanship and beauty of appearance which are characteristic of the cartographic productions of the Hydrographic Office.

35. *Cruise VII of the Carnegie*—The *Carnegie* sailed from Honolulu and arrived at Pago Pago, American Samoa, November 17. Leaving Pago Pago November 28 the vessel arrived at Apia on the same day it having been the intention to determine there the reduction-factor for atmospheric-electric potential-gradient records on the ship before proceeding to Sydney. The catastrophe following an explosion while loading gasoline at Apia on November 29 costing the lives of Captain J. P. Ault and Cabin-Boy Anthony Kolar and in which the vessel and her complete equipment were destroyed by fire brought to an untimely end Cruise VII (see v. 33, pp. 1-10). Radio communication had been excellent throughout this passage. New features of the bottom configuration continued to be found. Thus a new peak 7,000 feet above the general level was discovered at 26°.6 north and 160°.3 west; in the vicinity of 15° north and 137° west the ocean-floor was found to be very irregular with hard bottom and fragments of volcanic lava. The chemical program on board now included determination of oxygen-content for water samples taken at various depths. Captain Ault reported by radio most interesting observations of the great counter equatorial current. Brief stops were made at Penryhn Island on November 10, and at Manahiki Island on November 12. A complete account of the tragic ending of this Cruise, so splendidly being executed under the leadership of Captain Ault will be given in the next number of the JOURNAL.

36. *Atmospheric Electricity at Kew Observatory*—The Annual Report of the Director of the Meteorological Office (London) for the year ended March 31, 1929, describes some experiments made with the apparatus used in connection with the Kelvin water-dropper electrograph; chief among these is an arrangement whereby insulation-tests can be recorded photographically in addition to being observed visually. Further progress was made in developing apparatus to obtain a continuous record of earth-air current.

Experiments with the Ebert instrument, designed to give the number of "small" ions in the atmosphere but which is known to capture "large" ions also, indicate that on some occasions the large ions are in the majority.

For many researches connected with atmospheric electricity it is desirable to make observations immediately above a level surface far removed from any obstacle arising above the general level of the ground. Experiments were made

for a method to eliminate such disturbance caused by the presence of the observer and instruments; as the result of these it was decided to construct an underground laboratory in the middle of a large field attached to the Observatory and work was started on it.

37. *Change in European Agency of the Journal*—It is with regret that we inform the readers of the JOURNAL that Messrs. Wheldon and Wesley, Ltd., of London, who with their predecessors, Messrs. William Wesley and Son, have been its European agents since 1896, have decided to discontinue their Subscription Department. Beginning with 1930, Messrs. E. G. Allen and Son, Ltd., 14 Grape Street, London, W. C. 2, England, will act in their stead as European agents of the JOURNAL.

38. *Errata*—On page 190, last paragraph, sixth and seventh lines, September 1929 number of the JOURNAL, instead of "For the radiation of the plane-parallel layer indefinitely thick" read "For the radiation of the plane-parallel layer infinitely thick."

Druckversehen im Aufsatze "Einige wichtige planetare Ursachen für die Schwankungen des Erdmagnetismus im Jahre 1927" von Franz Göschl, im Septemberhefte, 1929, S. 215-223. Der Verfasser bittet um Berichtigung einiger, durch Undeutlichkeiten im Manuskript verursachter Druckversehen. Seite 217, Zeile 9 von unten lies "Uranus-" statt "Neptun-". In der Tabelle Seite 222, lies Jan. 7 und Apr. 14, "1.9" statt "1.0"; Aug. 20, "2.0" statt "0,2"; Okt. 11, "0.9" statt "0.0". Seite 223 unter SK=Solar Konjunktionen lies Jan. 28, Mai 20, und Sept. 2 "obere" Merkur-Sonnenkonjunktion.

39. *Personalia*—The Council of the Royal Meteorological Society has awarded the Symons gold medal for 1930 to *Dr. G. C. Simpson*, F. R. S., director of the Meteorological Office, London, for distinguished work in meteorological science. The medal will be presented at the Annual Meeting on January 15, 1930.

Dr. *F. Lindholm*, First Swedish State Meteorologist, who was released by his Government in 1926 that he might assume the directorship of the Physikalisch-Meteorologisches Observatorium Davos, founded by Dr. C. Dorno, has given up that post in order to resume his former position. He is succeeded in the directorship of the Davos Observatory by Dr. *W. Mörikofer.*

Dr. *Harlan T. Stetson* has been appointed Director of the Perkins Observatory of the Ohio Wesleyan University, Delaware, Ohio.

Dr. *F. E. Smith*, Director of Scientific Research at the British Admiralty since 1920, has been appointed Secretary to the Committee of the Privy Council for Scientific and Industrial Research, effective from October 1, 1929.

H. F. Johnston, Observer-in-Charge of the Watheroo Magnetic Observatory, attended as representative of the Carnegie Institution of Washington, the Second Conference of Physicists, Mathematicians, and Astronomers, held August 20 to 23, 1929, in Melbourne, Australia. He presented before the Conference three papers by members of the Observatory staff, namely, "The effect of condensation-nuclei on atmospheric-electric elements" and "Preliminary note on the atmos

pheric potential recorded with ionium-collectors" by G. Builder, and "Directional recording of atmospherics at Watheroo" by F. W. Wood.

Dr. *Gregory Breit*, since July 1, 1924, mathematical physicist in the Department of Terrestrial Magnetism, resigned his position last September in order to accept the post of professor of physics at the New York University. In addition to his regular work in instruction, he will have charge of postgraduate work in atomic physics. He will, however, continue his association with the Department of Terrestrial Magnetism as a research associate of the Carnegie Institution of Washington. Dr. *M. A. Tuve*, of the Department staff, so long associated with Dr. Breit, will have charge of the experimental investigations in high potential and atomic physics, previously conducted by Dr. Breit.

Dr. *Max Mason*, director of the Natural Science Division of the Rockefeller Foundation, has been elected president of the Foundation.

Rev. *Francis A. Tondorf*, director of the Georgetown Seismological Observatory, Washington, D. C., died on November 29, 1929, aged 59 years.

On March 8, 1929, *H. Abels*, formerly director of the Magnetic and Meteorological Observatory at Ekaterinberg (Sverdlovsk), died at the advanced age of 82 years. He was born on April 15, 1846, at Pernau, Livonia, and studied at the University of Dorpat. After teaching for a short time in Moscow, he entered in 1875, as senior observer, the service of the Physical Central Observatory in which he remained for 52 years. In 1879 he was assigned to the Magnetic and Meteorological Observatory at Pavlovsk and in 1885 he was appointed director of the new observatory which was to be established at Ekaterinburg which he developed and conducted with the greatest zeal for forty years. The exigencies of his arduous duties prevented him from devoting to purely scientific investigations the time which his knowledge and talents justified. However, he published about thirty papers during his lifetime and several more still remain unprinted because of unfavorable economic conditions.

Prof. Dr. *Peter Polis*, Director of the Meteorological Observatory, Chief of the Public Weather Service, and Professor at the Technical High School in Aachen, Germany, died on November 2, 1929, at the age of 59 years.

We regret to report the death on October 15, 1929; of Dr. *Edwin E. Slosson* at Washington, D. C., aged 64 years. Dr. Slosson had held since its establishment in 1921, the important post of director of Science Service which has rendered valuable service as an agency for the dissemination of popular knowledge on scientific subjects.

Captain *James Percy Ault*, Commander of the ship *Carnegie*, lost his life, at the age of 48 years, in the disaster overtaking that vessel at Apia, Western Samoa, November 29, 1929 (see pages 273-280).

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Agincourt and Meanook Observatories. Results of observations at the Canadian Magnetical Observatories, Agincourt and Meanook. The year 1924. Prepared by W. E. W. Jackson under the supervision of Sir Frederick Stupart. Ottawa, F. A. Acland, 1929 (41 with 6 pls.). 29 cm.

Chapman, S. Electric and magnetic fields of the Sun. Abstract: Observatory, London, v. 52, July, 1929 (193-195). [Paper presented at the meeting of the Royal Astronomical Society, London, June 14, 1929.]

Coimbra, Instituto Geofísico. Observações meteorológicas, magnéticas e sismológicas feitas no Instituto Geofísico (Observatório Meteorológico, Magnético e Sismológico) no ano de 1925. 2a parte—Magnetismo terrestre, Vol. LXIV. Coimbra, Tip. da Grafica Conimbricense, Limitada, 1928 (v+44). 29 cm.

Curry, P. A. Magnetic declination in the Nile Valley for the epoch 1930.0. Cairo, Physical Dept., Helwan Obs. Bull. No. 34, 1929 (2 with isogonic map). 25 cm.

Fisk, H. W. Secular variation of magnetic intensity and its accelerations in Pacific countries. Proc. Fourth Pacific Sci. Cong., Java, 1929 (517-534). 24 cm.

Haalck, H. Zur Frage der Erklärung der Kursker magnetischen und gravimetrischen Anomalie. Beitr. Geophysik, Leipzig, Bd. 22, 1929 (241-255; 385-399).

Hamburg, Deutsche Seewarte. Einundfünfzigster Jahresbericht über die Tätigkeit der Deutschen Seewarte für das Jahr 1928. Bearbeitet von der Centralabteilung der Deutschen Seewarte. Hamburg, 1928 (55). 27 cm. [On pp. 16-19 is a report of the Abteilung II (Instrumente und Schiffslaternen; Erd- und Schiffsmagnetismus).]

India, Meteorological Department. India weather review. Annual summary for 1927. Published by authority of the Government of India under the direction of C. W. B. Normand, Director General of Observatories. Calcutta, Govt. India, Central Pub. Branch, 1929 (97-316). 30 cm. [On pages 213-216 is given a report on solar and magnetic activity with tables containing the mean monthly values of the magnetic elements, the magnetic character of each day, and list of days selected as "quiet" during 1927, together with the annual mean values of magnetic elements for 1923 to 1927, all obtained from the magnetic record of the Alibag Observatory.]

London, Meteorological Office. Annual report of the director of the Meteorological Office presented by the Meteorological Committee to the Air Council for the year ended 31st March 1929. London, H. M. Stationery Office, 1929 (46). 24 cm. [Contains brief reports on Kew, Eskdalemuir, Lerwick, and Valentia observatories.]

The observatories' year book 1927, comprising the meteorological and geophysical results obtained from autographic records and eye observations at the observatories at Lerwick, Aberdeen, Eskdalemuir, Cahirciveen (Valentia Observatory), and Richmond (Kew Observatory), and the results of soundings of the upper atmosphere by means of registering balloons. London, H. M. Stationery Office, 1929 (430). 31 cm.

MOUNT WILSON OBSERVATORY. Summary of Mount Wilson magnetic observations of sunspots for May to August, 1929. Pub. Astr. Soc. Pacific, San Francisco, Cal., v. 41, 1929 (278-281; 312-316).

MURAMOTO, A. Weekly magnetic observations at Zinsen, Taihoko, Otomari, and Palau during 1928. Hydrogr. Bull., Tokyo, 8th year, No. 7, July 1, 1929 (299-302). [Text in Japanese language.]

NIPPOLDT, A. Ergebnisse der magnetischen Beobachtungen in Potsdam und Seddin im Jahre 1927 mit einem Gesamtsachregister aller Jahrgänge der Reihe 1890 bis 1927. Berlin, Veröff. met. Inst., Nr. 363, 1929 (44 mit 1 Kurventafel und 6 losen Kurvenblättern). 33 cm.

PRAGUE, INSTITUT GÉOPHYSIQUE NATIONAL TCHÉCOSLOVAQUE. Bulletin magnétique. Année 1, No. 1. Praha, 1929 (24). 24 cm. [Contient les valeurs de la déclinaison magnétique obtenues à l'observatoire de Stará Dala pendant les années 1927 et 1928.]

PUIG, I. La ciencia magnética en sus relaciones con la geografía. Madrid, R. Soc. Geográfica, 1929 (34 con 4 figuras). [Popular lecture on terrestrial magnetism with particular reference to the magnetic work done in Spain and the construction of the magnetic charts of Spain for the epoch 1924, reproductions of which accompany the text.]

ROSE, H. W., AND N. N. TRUBIATCHINSKY. Brief manual for magnetic-survey work. Leningrad, Central Geophysical Observatory, 1928 (114). 24 cm. [Contents: General remarks; astronomical observations for magnetic survey; determination of magnetic declination with Brunner-Chasselon theodolite; determination of horizontal intensity with Brunner-Chasselon theodolite; determination of horizontal intensity with electric magnetometer; determination of inclination with dip-circle; determination of inclination with earth inductor; reduction of observations to epoch. Text is in the Russian language.]

RYD, V. H. The departures of the daily means. Copenhague, Met. Inst., Comm. Mag., No. 7, 1929 (30). 25 cm.

TORTOSA, OBSERVATORIO DEL EBRO. Resumen de las observaciones solares, electro-meteorológicas y geofísicas efectuadas durante el año 1928. Tortosa, Bol. Obs. Ebro, v. 19, 1929 (223-273). [Contains annual summary of observations in terrestrial magnetism and electricity.]

TRAFELLI, L. Sole e terra magneti in presenza. Nuovi indirizzi di recerche in geofisica e in astrofisica. Roma, Casa Edit. l'Elettricista, 1929 (68). 26 cm.

YANOVSKY, B. M. Methods of obtaining permanent magnets in magnetometers for measuring the horizontal component of the Earth's field. J. Geophys., Leningrad, v. 6, No. 1, 1929 (1-16). [Russian text with English summary.]

B—Terrestrial and Cosmical Electricity

BĚHOUNEK, F. Die im Luftschiffe "Italia" zur Beobachtung der atmosphärischen Elektrizität angewandten Methoden und Apparate. Arktis, Gotha, Jahrg. 2, Heft 3, 1929 (69-76).

BENADE, J. M. Atmospheric electricity during sandstorms. Science, New York, N. Y., N. S., v. 70, Oct. 18, 1929 (379-380). [Brief note in connection with one by R. H. Canfield bearing the same title which appeared in *Science* for May 3, 1929, pp. 474-475.]

BIDER, M. Ueber den Einfluss meteorologischer Faktoren auf das luftelektrische Potentialgefälle nach den Davoser Registrierungen an Normaltagen. Festschr. 110. Jahresversammlung Schweiz. Natf. Ges., Davos, 1929 (65-81).

BOTHE. W., UND W. KOLHÖRSTER. Das Wesen der Höhenstrahlung. Zs. Physik, Leipzig, Bd. 56, Heft 11 u. 12, 1929 (751-777).

Die Natur der Höhenstrahlung. Physik. Zs., Leipzig, Jahrg. 30, No. 17, 1929 (516-517).

CONRAD, V. Zur Vierteljahrhundertfeier der Carnegie Institution of Washington. Leipzig, Beitr. Geophysik, Bd. 23, Heft 4, 1929 (353-355). [Contains special reference to the work of the Department of Terrestrial Magnetism.]

CURTISS, L. F. The nature of cosmic radiation. Phys. Rev., Menasha, Wis., v. 34, Nov. 15, 1929 (1391).

DAS, A. K. On the quantum of cosmic radiation and the relative mass of proton and electron. Naturw., Berlin, Jahrg. 17, Heft 43, 1929 (841).

DEPPERMANN, C. E. Initial studies in atmospheric electricity at the Manila Observatory, October 1927-December 1928. Manila, Weather Bureau, 1929 (17 with 25 figs.). 29 cm.

DUFAY, J. La raie verte des aurores polaires dans la lumière du ciel nocturne. J. Physique et Le Radium, Paris, T. 10, No. 5, 1929 (93 S—94 S). [Résumé d'une communication faite à la Section de Lyon de la Société Française de Physique, Séance du 11 mai 1929.]

ERIKSON, H. A. Factors affecting the nature of ions in air. Phys. Rev., Menasha, Wis., v. 34, No. 4, 1929 (635-643).

EVE, A. S., D. A. KEYS, AND F. W. LEE. The penetration of rock by electromagnetic waves and audio frequencies. New York, N. Y., Proc. Inst. Radio Eng., v. 17, Nov., 1929 (2072-2074).

FRÉEDERIKSZ, V. Electrical prospecting of ore-bodies based upon measurement of alternating magnetic fields. Leningrad, Comité Géophysique, 1929 (137 with 92 figs.). 26 cm. [Série des travaux sur les méthodes de prospection et sur la géophysique, No. 5. Russian text with English summary.]

GORTNER, R. A. Atmospheric electricity during sand storms. Science, New York, N. Y., N. S., v. 70, Aug. 2, 1929 (118-119).

GREEN, R. W. Summer thunderstorms. Met. Mag., London, v. 64, Sept., 1929 (186). [Brief note regarding types of summer thunderstorms occurring at night.]

HAFSTAD, L. R., AND M. A. TUVE. Further studies of the Kennelley-Heaviside layer by the echo-method. New York, N. Y., Proc. Inst. Radio Eng., v. 17, No. 9, 1929 (1513-1522).

An echo-interference method for the study of radio wave-paths. New York, N. Y., Proc. Inst. Radio Eng., v. 17, No. 10, 1929 (1786-1792).

HELLMANN, H. Ueber das Auftreten von Ionen beim Zerfall von Ozon und die Ionisation der Stratosphäre. Ann. Physik., Leipzig, Bd. 2, Heft 6, 1929 (707-732).

HULBURT, E. O. Ions and electrical currents in the upper atmosphere. Science, New York, N. Y., N. S., v. 70, Aug. 30, 1929 (216).

Ionization in the atmosphere of Mars. New York, N. Y., Proc. Inst. Radio Eng., v. 17, No. 9, 1929 (1523-1527).

HUMMEL, J. N. Der scheinbare spezifische Widerstand. Zs. Geophysik, Braunschweig, Jahrg. 5, Heft, 3/4, 1929 (89-104). [Einige geolektrische Methoden fussen auf der Bestimmung des "scheinbaren spezifischen Widerstandes." Der Begriff des scheinbaren spezifischen Widerstandes wird erklärt, verschiedene Wege zu seiner Ermittlung aufgezeigt und die Theorie der betreffenden Aufschlussmethoden entwickelt. Letztere erweisen sich zur Auffindung von Störungskörpern als geeignet; ihr eigentliches Anwendungsgebiet ist aber die Beschreibung des horizontal geschichteten Untergrundes. Die Rechnungen werden für zwei spezielle Fälle durchgeführt und die Ergebnisse diskutiert.]

Modellversuche mit der Viertelwellenmethode. Zs. Geophysik, Braunschweig, Jahrg. 5, Heft 3/4, 1929 ((104-117).

ISRAËL, H. Kritische Bemerkungen zu der Arbeit von R. Stoppel: Untersuchungen über die Schwankungen der lokalen elektrischen Ladung der Erde. Beitr. Geophysik, Leipzig, Bd. 22, Heft 1/2, 1929 (133-137).

KULENKAMPFF, H. Bemerkungen zum Absorptionsgesetz der durchdringenden Höhenstrahlung. Physik. Zs., Leipzig, Jahrg. 30, Nr. 18, 1929 (561-567).

LAUTNER, P. Die luftelektrischen Verhältnisse am Zugspitzgipfel in 2960 m. (Deutsches Meteorologisches Jahrbuch für Bayern 1928, C. S. 1-19, München 1929.) Besprechung von K. Kähler: Met. Zs., Braunschweig, Bd. 46, Heft 10, 1929 (409-410).

LEE, F. W., J. W. JOYCE, AND P. BOYER. Some earth resistivity measurements. Washington, D. C., Dept. Comm., U. S. Bur. Mines, Inf. Cir. 6171, Oct., 1929 (16 with 25 figs.). 27 cm.

LINDHOLM, F. Registrierbeobachtungen der Hessschen Ultra-γ-Strahlung auf Muottas-Muraigl (2456 m). II. Mitteilung. Beitr. Geophysik, Leipzig, Bd. 22, Heft 1/2, 1929 (141-163).

LUGEON, J. La genèse des orages de chaleur et leur prévision. Paris, C.-R. Acad. sci., T. 189, No. 9, 1929 (363-365).

MCADIE, A. An unusual lightning flash. Washington, D. C., Mon. Weath. Rev., v. 57, May, 1929 (197-198 with 7 figs.).

MATHIAS, E. Contribution à l'étude de la matière fulminante. La tension superficielle. Partage d'un globe en plusieurs autres sous l'influence d'un choc ou d'un rebondissement. Paris, C.-R. Acad. sci., T. 189, No. 15, 1929 (512-514).

MILLIKAN, R. A., AND G. H. CAMERON. New results on cosmic rays. Washington, D. C., Smithsonian Inst., Rep. 1928 (213-231).

MÜLLER, M. Geophysikalische Feldmessung mit niederfrequenten Wechselströmen. Zs. Geophysik, Braunschweig, Jahrg. 5, Heft 5/6, 1929 (256-359).

NIPPOLDT, A. Magnetische Kräfte über dem Meere. Berlin, E. S. Mittler u. Sohn, 1929 (28 mit 8 Abb.). 22 cm. [Meereskunde. Sammlung volkstümlicher Vorträge zum Verständnis der nationalen Bedeutung von Meer und Seewesen herausgegeben vom Institute für Meereskunde, Berlin. Heft 185.]

OSLO, NORWEGISCHES METEOROLOGISCHES INSTITUT. Jahrbuch des Norwegischen Meteorologischen Instituts für 1928. Oslo, Gröndahl & Sön, 1929 (xii+170). 31 cm. [Contains values of the atmospheric-electric potential-gradient and conductivity as observed at the Aas Meteorological Observatory in 1928.]

PUIG, I. Un nuevo colector de potencial eléctrico del aire para observaciones de campo. An. Soc. Espan. Met., Madrid, v. 3, Núm. 1, 1929 (10-14).

RAYLEIGH (LORD). Some problems of cosmical physics, solved and unsolved. Science, New York, N. Y., v. 70, July 26, 1929 (77-84). [Contains discussion of the auroral spectrum.]

SCHELLENG, J. C. Further note on the ionization of the upper atmosphere. New York, N. Y., Proc. Inst. Radio Eng., v. 17, No. 8, 1929 (1313-1315).

SCHINDELHAUER, F. Elektromagnetische Störungen II. Elektr. Nachr.-Technik, Berlin, Bd. 6, Heft 6, 1929 (231-236).

SLIPHER, V. M., UND L. A. SOMMER. Zur Deutung des Nordlichtspektrums. Naturw., Berlin, Jahrg. 17, Heft 41, 1929 (802-803).

SREENIVASAN, K. On the relation between long-wave reception and certain terrestrial and solar phenomena. New York, N. Y., Proc. Inst. Radio Eng., v. 17, No. 10, 1929 (1793-1814). [The author finds good correlation between atmospheric ozone in Northwestern Europe and Bangalore (India) reception, and between the two and sunspots. Little correlation is found between these and terrestrial magnetism as represented by the international magnetic-character numbers. Analysis of the data on the basis of the 27-day period has yielded very satisfactory agreement between reception and sunspots, with a six-day period in reception for which no explanationis found.]

Störmer, C. The spectrum of sunlit aurora rays as compared with the spectrum of lower aurora in the Earth's shadow. Nature, London, v. 124, Aug. 17, 1929 (263-264).

Kurzwellenechos, die mehrere Sekunden nach dem Hauptsignal eintreffen, und wie sie sich aus der Theorie des Polarlichtes erklären lassen. Naturw., Berlin, Jahrg. 17, Heft 33, 1929 (643-651).

Sonnenbelichtete Nordlichtstrahlen. Zs. Geophysik, Braunschweig, Jahrg. 5, Heft 5/6, 1929 (177-194).

Swann, W. F. G. Theory of the charging effect on an insulated body exposed to primary corpuscular radiation or to corpuscular radiation initiated by the cosmic radiation. Philadelphia, Pa., J. Frank. Inst., v. 208, Aug., 1929 (259-274).

Swann, W. F. G., and A. Longacre. An endeavor to detect a corpuscular current entering the Earth. Philadelphia, Pa., J. Frank. Inst., v. 208, Aug., 1929 (275-282).

Towne, H. M. The lightning arrester and factors affecting its performance and application. Gen. Elec. Rev., Schenectady, N. Y., v. 32, Aug., 1929 (428-436). [This article deals with the action of arresters under different conditions of service; location, grounding, and values of circuit constants; and of the degree of protection afforded in the various cases.]

Tscherniawsky, E. A. Luftelektrizität und geophysikalische Grundlagen der Elektroionenkultur. Taschkent, Mittelasiatisches Met. Inst., Geophys. Observatorium, Luftelektr. Abt., 1928 (28). 25 cm. [Ein Vortrag der zur VI. Physikertagung der U. S. S. R. gehalten wurde. Die Arbeit besteht im wesentlichen in der Bestimmung des Zusammenhangs zwischen den Vorgängen des Wachstums und den Elementen der Luftelektrizität. Russisch mit deutscher Zusammenfassung.]

Walter, B. Ueber die in dieser Zeitschrift (Met. Zs., Bd. 18, 1901, 80-81) von G. Lachmann Beschriebene Blitzaufnahme. Met. Zs., Braunschweig, Bd. 46, Heft 9, 1929 (337-344).

Wölcken, K. Bericht über den jetzigen Stand der Untersuchungen über die durchdringende Höhenstrahlung. Zs. Geophysik, Braunschweig, Jahrg. 5, Heft 3/4, 1929 (151-159).

C—Miscellaneous

American Institute of Mining and Metallurgical Engineers. Geophysical prospecting. Papers and discussions presented at meetings held at New York, February, 1928, and at Boston, August, 1928. New York, Amer. Inst. Min. Metal. Eng., 1929 (676). 23 cm.

Amsterdam, Kon. Akademie von Wetenschappen. Science in the Netherlands East Indies. Edited by L. M. R. Rutten. Amsterdam, 1929 (viii+432 with illus.). 27 cm. [This book was prepared and published for the convenience of the visitors of the Fourth Pacific Science Congress, held in Java, May, 1929. It contains a series of contributions dealing with the various branches of scientific research in the Dutch East Indies, among which is a brief article by E. van Everdingen on "Terrestrial Magnetism" pp. 46-49.]

Anderson, W. Ueber die Bildung des Ozons in den höchsten Atmosphärenschichten. Physik. Zs., Leipzig, Jahrg. 30, Nr. 15, 1929 (485-487).

Brooks, C. F. The relation between the duration of bright sunshine registered by a Campbell-Stokes sunshine recorder and the estimated amount of cloud. London, Met. Office, Prof. Notes No. 53, 1929 (15). 24 cm.

Brooks, C. F. Meteorological program of the seventh cruise of the *Carnegie*, 1928-1931. Washington, D. C., Mon. Weath. Rev., v. 57, May, 1929 (194-196 with 7 figs.).

Campbell, W. W. Terrestrial magnetism. Toronto, J. R. Astr. Soc. Can., v. 23, Nov., 1929 (406-410). [Address given at the celebration of the 25th anniversary of research of the Carnegie Institution of Washington, on board the non-magnetic ship *Carnegie*, San Francisco, Aug. 26, 1929.]

Carnegie Institution of Washington. The second celebration of the twenty-fifth anniversary of research in the Carnegie Institution of Washington. Science, New York, N. Y., N. S., v. 70, Sept. 13, 1929 (243-250). [Account of the celebration held on board the non-magnetic ship *Carnegie* in San Francisco Harbor on August 26, 1929, accompanied by the various addresses given on that occasion.]

Collins, G. N., L. H. Flint, and J. W. McLane. Electric stimulation of plant growth. J. Agric. Res., Washington, D. C., v. 38, No. 11, 1929 (585-600).

Comité Météorologique International. Offices météorologiques du monde avec leurs directeurs et états-major, l'extension des services, et leurs publications. (Secrétariat du Comité Météorologique International, Pub. No. 2). Utrecht, Kemink & Zoon, 1929 (110). 29 cm.

Dobson, G. M. B. L'ozone atmosphérique. J. Physique et Le Radium, Paris, v. 10, No. 7, 1929 (241-246). [After mentioning the methods of measurement, the author considers the variations of the ozone-layer according to place and season. There is a regular annual course which is different for different latitudes; there are also variations connected with general meteorological conditions. The causes of these phenomena are discussed.]

Eve, A. S., and D. A. Keys. Applied geophysics in the search for minerals. Cambridge, University Press, 1929 (viii+253 with illus.). 22 cm.

Göschl, F. Kosmisch-planetare Ursachen für Klimaschwankungen. Met. Zs., Braunschweig, Bd. 46, Heft 8, 1929 (306-311).

Götz, F. W. P., and G. M. B. Dobson. Observations of the height of the ozone in the upper atmosphere. Part II. London, Proc. R. Soc., A, v. 125, No. 797, 1929 (292-294).

Fleming, J. A., and J. P. Ault. Cruise VII of the *Carnegie* 1928-31 in the Pacific and Indian Oceans. Proc. Fourth Pacific Sci. Cong., Java, 1929 (547-560 with 11 pls.). 24 cm.

Hartmann, W. Erdbodennahe Haloerscheinungen. Met. Zs., Braunschweig, Bd. 46, Heft 7, 1929 (269-270).

Holzapfel, R. Haloerscheinung auf der Stolzalpe (Steiermark) am 19. Februar 1929 vormittags. Met. Zs., Braunschweig, Bd. 46, Heft 8, 1929 (323-324).

Johansson, O. V. Frans Carl Otto August Ernst Biese. Minnesteckning av Osc. V. Johansson. Helsingfors, Mitt. Met. Inst. Univ., No. 9, 1928 (56 with portrait). 24 cm.

Lindholm, F., und W. Mörikofer. Das Schweizerische Forschungsinstitut für Hochgebirgsklima und Tuberkulose in Davos. Abteilung I: Das Physikalisch-Meteorologische Observatorium. Festschr. 110. Jahresversammlung Schweiz. Natf. Ges., Davos, 1929 (1-20 mit 11 Abb.). [On pages 14-17 is an account of the atmospheric-electric work.]

Mathias, O., und V. F. Hess. Ueber einen neuen Apparat zur Registrierung der Ausschläge von Ein- und Zweifaden-Elektrometern. Physik. Zs., Leipzig, Jahrg. 30, No. 16, 1929 (508-512).

Maurain, Ch. Le méthodes géophysiques pour l'étude des couches superficielles du sol. Paris, La Revue Pétrolifère, 1929 (29). 21 cm. Prix 10 francs. [A concise digest of our present knowledge of the subject of geophysical prospecting. The various methods now in use are described and their application and relative importance indicated.]

Melbourne, Bureau of Meteorology. Results of rainfall observations made in Western Australia including all available annual rainfall totals from 1374 stations for all years of record up to 1927, with maps and diagrams, and record of notable meteorological events, also appendices presenting monthly and yearly meteorological elements of Perth, Broome, and Kalgoorlie. Published . . . under the direction of H. A. Hunt, Commonwealth Meteorologist. Melbourne, H. J. Green, Govt. Printer, 1929 (xiv+387 with maps). 30 cm. [Contains records of Aurora Australis, earthquakes, thunder and lightning in Western Australia.]

Moureau, P. Le rayon vert—Les ombres colorées. Reproduction artificielle de ces phénomènes. Nature, Paris, T. 57, No. 2818, 1929 (294-299).

National Physical Laboratory, Teddington. Report for the year 1928. London, Dept. Sci. Indust. Res., 1929 (vi+283). 26 cm. [Contains note regarding the behavior of the vertical-force variometer which had been in successful operation at the Abinger Observatory for about three months and regarding which a short account is to be written as soon as sufficient data have been obtained. A report on the investigation of pivots and jewels in instruments undertaken for the Physics Co-ordinating Research Board is given on page 193.]

New Zealand. Ninth annual report of the Government of New Zealand on the administration of the Mandated Territory of Western Samoa for the year ended 31st March 1929. Wellington, W. A. G. Skinner, Govt. Printer, 1929 (36 with maps and illus.). 34 cm. [On p. 16 is a brief account of the work of the Apia Observatory.]

Planck, M. Das Weltbild der neuen Physik. Wien, MonHfte. Math. Phys., Bd. 36, Heft 2, 1929 (387-410).

Simpson, G. C. Meteorology in polar regions. London, Geog. J., v. 74, Sept., 1929 (258-270). [A paper read before the Royal Geographical Society, London, on May 6, 1929, in which the author discusses the kind of meteorological work which should be undertaken in polar regions particularly with reference to the proposed repetition of the great Polar Year of 1882-1883 in 1932. He insisted on the need of simultaneous observations taken in all parts of the polar regions and of unbroken records extending over several years at a few representative stations. Dr. Chapman, in discussing the paper emphasized the need of a magnetic survey of the arctic regions and also of establishing a few permanent stations in order that reliable magnetic maps may be constructed and kept current for use in possible transarctic aviation. He further stressed the need of more knowledge of terrestrial magnetism in and near the zone of maximum auroral frequency.]

Union Géodesique et Géophysique Internationale. Section de Météorologie. Troisième Assemblée Générale: Prague, 1927. I. Report on photometers for a survey of the reflectivity of the Earth's surface, by L. F. Richardson. II. Atmospheric dust: Observations with the Owens dust-counter. 1. United States, Washington, January 1925 to July 1927. 2. Australia, Melbourne, September 1924 to June 1927. 3. Finland. (Aitken dust-counter.) Report by G. Melander. Cambridge, University Press, 1928 (47). 24 cm.